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WETLANDS RESEARCH PLAN
NOVEMBER, 1985

by

Joy B. Zedler, Professor
Department of Biology
San Diego State University
San Diego, California 92182-0057

and

Mary E. Kentula, Assistant Professor
Department of General Science
Oregon State University
Corvallis, Oregon 97333

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Project Officer

Harold V. Kibby, Chief
Toxics/Pesticides Branch
Environmental Research Laboratory
Corvallis, Oregon 97333

ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CORVALLIS, OREGON 97333

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This plan describes the research necessary to assist the EPA in carrying out its responsibilities relative to wetlands, including Section 404 of the Clean Water Act. There are both operational and policy implications to the proposed research. Many of the products will aid 404 personnel in evaluating permit applications. Some will aid EPA in determining the relative importance of wetlands in altering water quality and, thus, help set policy determining the scope of wetlands protection.

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TABLE OF CONTENTS

Page

I. Introduction 1

I.A. Planning approach
    I.A.1. Advice from EPA Headquarters and Regions
    I.A.2. Input from other agencies
    I.A.3. Input from wetland science and scientists
    I.A.4. Conclusion

I.B. Structural framework for proposed research
    I.B.1. Wetland values--What are they?
    I.B.2. What information is needed to carry out Section 404?
    I.B.3. Which information should EPA develop?
        I.B.3.a. Water quality
        I.B.3.b. Cumulative impacts
        I.B.3.c. Mitigation
    I.B.4. Recommendations for the roles of other Agencies
    I.B.5. How do the efforts of EPA, COE, and FWS fit together into an integrated, comprehensive program of wetland research?
    I.B.6. How do the three areas of research recommended for EPA compare scientifically?

II. The research plan 16

II.A. Water quality and related hydrologic functions 16
    II.A.1. Background and rationale
    II.A.2. State of knowledge
    II.A.3. Planning a coordinated approach
    II.A.4. Rate Functions
        II.A.4.a. Objectives: to determine retention/transformation rates and factors influencing rates; risk assessment
        II.A.4.b. Rationale
        II.A.4.c. Research approach: field and mesocosm experiments
        II.A.4.d. Time line and cost
    II.A.5. Interactions among nutrients, organics and heavy metals, and their impacts on the water quality function
        II.A.5.a. Objectives: to identify interactions & controlling processes; assess impacts

Page

- II.A.5.b. Rationale
- II.A.5.c. Research approach: multiple factor experiments
- II.A.5.d. Time line and cost
- II.A.6. Models and simple descision criteria
  - II.A.6.a. Objectives: model the water quality of freshwater wetlands; design simple decision criteria; assess cumulative roles of wetlands within watersheds and ecoregions
  - II.A.6.b. Rationale
  - II.A.6.c. Research approach: collate research data; construct models
  - II.A.6.d. Time line and cost

- II.B. Cumulative impact assessment 34
  - II.B.1. Background and rationale
  - II.B.2. State of knowledge
  - II.B.3. Document past knowledge
    - II.B.3.a. Objective: document past losses
    - II.B.3.b. Rationale
    - II.B.3.c. Research approach: "cost-benefit" analysis before proceding with recommended research
    - II.B.3.d. Time line and cost
  - II.B.4. Relate functional losses to area losses
    - II.B.4.a. Objective: relate functional losses to area losses and model cumulative impacts of piecemeal habitat losses
    - II.B.4.b. Rationale
    - II.B.4.c. Research approach: feasibility study before proceeding with recommended research
    - II.B.4.d. Time line and cost

- II.C. Mitigation 47
  - II.C.1. Background and rationale
  - II.C.2. State of knowledge
  - II.C.3. Success of past mitigation projects
    - II.C.3.a. Objective: catalog and evaluate past mitigation projects
    - II.C.3.b. Rationale

Page

II.C.3.c. Research approach: survey Regions
II.C.3.d. Time line and cost
II.C.4. Experimental component
II.C.4.a. Objective: develop experimental component large-scale mitigation projects
II.C.4.b. Rationale
II.C.4.c. Research approach
II.C.4.d. Time line and cost

III. Associated research and recommendations for other Federal agencies 56

III.A. Ecosystem syntheses of target wetland types
III.B. Long-term studies of bottomland hardwoods
III.C. Quantifying hydrological and food chain support functions
III.D. Wetland delineation research
III.E. Wetland value assessment methodology

IV. Technical information transfer 62

V. Summary of recommendations 63

VI. Literature cited 68

Appendices 72

I. Summaries of interviews with EPA's Regional Offices 72
II. Summaries of research plans from the Fish and Wildlife Service and the Army Corps of Engineers 84
III. Members of the Interagency Wetlands Coordinating Committee 90
IV. The status of wetland science--Summaries of selected papers 92
V. List of scientists consulted in developing the research plan 106
VI. Workshop participants 107
VII. List of scientists who reviewed the draft plan 108
VIII. Opportunities for research on cumulative impact assessment and mitigation techniques 112

THE ENVIRONMENTAL PROTECTION AGENCY'S WETLAND RESEARCH PLAN, NOVEMBER 1985

I. INTRODUCTION

This plan describes the research necessary to assist the Environmental Protection Agency (EPA) in carrying out its responsibilities relative to wetlands, including Section 404 of the Clean Water Act. There are both operational and policy implications to the proposed research. Many of the products will aid 404 personnel in evaluating permit applications. Some will aid EPA in determining the relative importance of wetlands in altering water quality and, thus, help set policy determining the scope of wetlands protection.

The introductory section describes the planning approach (I.A.), indicating the many sources of advice, and outlines the structural framework for identifying research needs (I.B.), demonstrating how the research program proposed for EPA fits into the overall wetland research effort being sponsored by the Federal government. The research program for EPA is then developed (II.), followed by more detailed descriptions of the plans of other agencies and recommendations of what might be added to those efforts (III.). Next, several mechanisms for technical information transfer are prescribed (IV.) so that the developing body of knowledge is continually made available to the intended audience of this research program. Recommendations for research are summarized within each segment, and an overall strategy for implementation is provided in Section V.

I.A. PLANNING APPROACH

I.A.1. Advice from EPA Headquarters and Regions

The planning effort has been guided by EPA Headquarters, EPA Regional Offices, other Federal agencies, the scientific literature, and individual scientists who are wetland experts.

Correspondence from EPA Headquarters (Davis 1985, Bretthauer 1985, Meagher 1985) outlined the major topics to be covered in a research plan. Guidance from EPA headquarters indicated that research efforts should:

- Develop a mechanism for structuring knowledge on wetlands values so that the Agency can evaluate individual wetlands decisions within a framework of national priorities,
- Provide additional scientific information on specific wetland functions, with a particular focus on water quality interactions, including sediment retention, and nutrient and toxicant uptake and release,
- Investigate ways to assess the cumulative impact of incremental loss of wetlands on a regional basis,
- Provide visible, authoritative, and scientifically credible information on major wetlands issues of concern to EPA, and
- Develop a plan that complements the efforts of other Federal agencies.

Information needs of the 404 personnel were obtained in visits to six Regional Offices and in telephone interviews and correspondence with all ten offices (Appendix I). Two areas were repeatedly indentified as urgent:

- The need to assess the cumulative impacts of the incremental loss of wetland habitat, and
- The need to devise suitable mitigation procedures and ways to assess mitigation success.

The means to document the water quality functions of a wetland and to predict the impacts of a proposed project on these functions are also needed. Moreover, a concern was voiced that there was little information available on particular wetland types, e.g., bogs and fens (see Appendix I).

Similar recommendations came from the National Wetland Values Assessment Workshop (Sather and Stuber 1984), which was sponsored in part by EPA. Participants recommended that research investigate:

- Cumulative impacts of nutrient, sediment, and anthropogenic substances,
- Water-sediment processes,
- Microbiology of wetland systems,

- Retention and processing of anthropogenic substances, and

- Long-term ecosystem dynamics of selected wetland sites.

Thus, there is wide agreement that the primary research needs are the quantification of water quality functions of wetlands, assessment of cumulative impacts and evaluation of mitigation procedures.

I.A.2. Input from other agencies

EPA and other agencies have recently sponsored reviews of the wetland literature to assess the status of knowledge and plan research programs. The Army Corps of Engineer's (COE) review of wetland research was developed for purposes that parallel this effort. Their proposed program of research (Clairain, et al. 1985) recommends substantial effort in understanding water quality, hydrologic and food chain support functions of bottomland hardwoods. Plans of the Fish and Wildlife Service (FWS) (Division of Biological Services, Research and Development, FWS, 1984) focus on habitat values and wetland delineation. These research plans are summarized in Appendix II.

The Interagency Wetlands Coordinating Committee is composed of representatives from about 20 agencies interested in wetlands (Appendix III). Initial ideas for this EPA research plan were presented at a meeting in Washington, D.C., on September 18, 1985. At that time, COE, FWS, and other agencies indicated their priorities for research in FY'86. The meeting concluded with a lengthy discussion of how the focus of each agency might fit together into an integrated research program. Other agencies endorsed the need for EPA to focus on water quality, cumulative impact and mitigation research with an emphasis on freshwater wetlands.

I.A.3. Input from wetland science and scientists

Input from wetland scientists was obtained in three ways: examination of literature reviews, discussion with wetland scientists, and evaluation of an early draft at a workshop with freshwater wetland specialists.

In a study sponsored by COE, Nixon and Lee (1985) reviewed the information base of water quality functions within each of seven geographic regions of the United States, identified information gaps, and recommended specific research to improve knowledge of water quality functions and to develop an understanding of key wetland types. Other reviews were sponsored by COE to evaluate hydrological, fish and wildlife habitat, and socioeconomic functions. The Soil Conservation Service (SCS) sponsored a review of the function of wetlands in improving the quality of runoff from agricultural lands (Dickerman et al. 1985). These and other literature reviews are summarized in Appendix IV.

A number of scientists (Appendix V) were contacted for input throughout the planning process. A workshop was held to review a preliminary draft of this research plan. Scientists from universities and EPA labs (Appendix VI) helped to clarify program goals and focus individual research objectives. Additional individuals (Appendix VII) were asked to review a draft plan.

I.A.4. Conclusion

Overall, the need appears to be greatest for information that will predict cumulative impacts of wetland loss, improve the formulation and evaluation of mitigation proposals, and quantify water quality functions of wetlands. An emphasis on freshwater--rather than coastal saline--wetlands was repeatedly suggested by agency personnel. Hence, these three information needs are given the highest priority, and it is recommended that freshwater systems be the primary focus of research funding. In the next section (I.B.), the priorities for EPA are fit into an overall scheme for Federal support of wetlands research.

The priorities listed here do not discount other information needs or imply that coastal wetlands are fully understood. Rather, they indicate what areas of study can best expand our knowledge in the near future. Furthermore, any research program must keep pace with new findings, new techniques, and new information demands. Thus, the research program must be adaptive--it must be able to change in ways that maximize benefits to the Agency.

EPA will need to reevaluate this program periodically to reassess priorities and justify continuation. Moreover, to ensure that the research program continues to function within an overall scheme for Federal support of wetlands research, EPA will need to identify a representative for the Interagency Wetlands Coordinating Committee who would interact with comparable personnel from COE, FWS, and other agencies.

Finally, this is a research plan and not a research proposal. It is expected that specific proposals will be developed to meet the objectives that are adopted by EPA. The goal is to identify the information needed to carry out Section

404 of the Clean Water Act and to recommend research that will develop the necessary information in a timely way.

I.B. STRUCTURAL FRAMEWORK FOR PROPOSED RESEARCH

I.B.1. Wetland values--What are they?

Section 404 of the Clean Water Act requires that wetlands be evaluated for a broad range of functions. The most comprehensive system of wetland valuation available has been developed by Paul Adamus for the Federal Highway Administration (FHWA) (Adamus 1983). This system, called simply the "Adamus technique" or the "FHWA technique", is under consideration by several Federal agencies to provide a basic framework upon which to develop a standard.

Value assessment strategies have undergone numerous reviews (Leonard et al. 1981, Sather and Stuber 1984, Whigham and Brinson 1985). The FHWA Technique has repeatedly been judged the most comprehensive inventory of functional values because it considers the three commonly accepted categories of wetland functions. These categories are commonly defined as

* Water quality functions, such as the uptake and/or transformation of nutrients, heavy metals, and anthropogenic substances,

* Hydrologic functions, such as flood storage and desynchronization, modification of ground water recharge and discharge, and shoreline stabilization, and

* Food chain support functions, such as habitat for fish, waterfowl, endangered species, and other wetland-dependent species.

Hence, the research proposed will fill information gaps that now prevent adequate assessment of wetland functions. The assumptions of the FHWA Technique are thus treated as hypotheses to be tested through this research program.

Although the FHWA Technique is adopted as a structural framework for this plan, it is recognized that there are still problems with its implementation as a system for comparing functional values of different wetlands. Several of these concerns were expressed by Bill Odum at the October 8 workshop. (Odum is using the FHWA Technique as part of a project that was funded by EPA, through FWS-National Coastal Ecosystem Team

(NCET) to gather information on eight wetland sites on Chincoteague Island, Virginia.) His concerns were:

1) The system is very sensitive to the amount of information available to evaluators, such that wetlands for which there is more information available tend to obtain higher scores

2) There may be factors within the design of the FHWA Technique which unevenly weight certain answers. This needs to be investigated with some sort of sensitivity analysis, and

3) The system assumes a linear relationship between wetland acreage and water quality function.

At present, at least one state (Wisconsin) has streamlined the procedure; other states are modifying the procedure for their specific needs. The COE is computerizing the FHWA Technique to expedite its evaluation and implementation. EPA is providing partial funding to the National Wetland Technical Council (NWTC) to sponser a series of seven regional workshops to evaluate the scientific literature upon which the FHWA Technique is based. NWTC is a group of scientists who bring scientific knowledge to bear on wetland issues at the national level. The first of these regional workshops (Pacific Regional Workshop, Mill Valley, California) was held in April 1985. The output of all workshops will be an evaluation of the assumptions that Adamus made in developing his assessment procedure, a list of literature not utilized by Adamus (1983), and suggestions for research. In addition, scientists are being asked to suggest potential sites for long-term wetland research, especially sites where there is a good record of hydrologic conditions.

I.B.2. What information is needed to carry out Section 404?

A complete body of knowledge on wetlands would include details of water quality, hydrologic and food chain support functions for all wetland types. To make decisions on permits requesting alteration of wetland areas, it is essential to know the impacts of disturbance on that wetland area, and on the functional values of that wetland and of the watershed and ecoregion where that wetland occurs. To make decisions on how to mitigate those lost values, it is necessary to know how other wetland areas can be enhanced, restored, or created in order to replace values that will be lost by granting each permit.

In summary, the required knowledge is of two types:

- The basic functioning of wetlands, and
- How those functions change
  - --with cumulative losses, and
  - --with mitigation projects.

In addition to these needs for information on wetland functions there must be

- Field techniques for assessing wetland boundaries, and
- Field techniques for assessing wetland functions.

I.B.3. Which information should EPA develop?

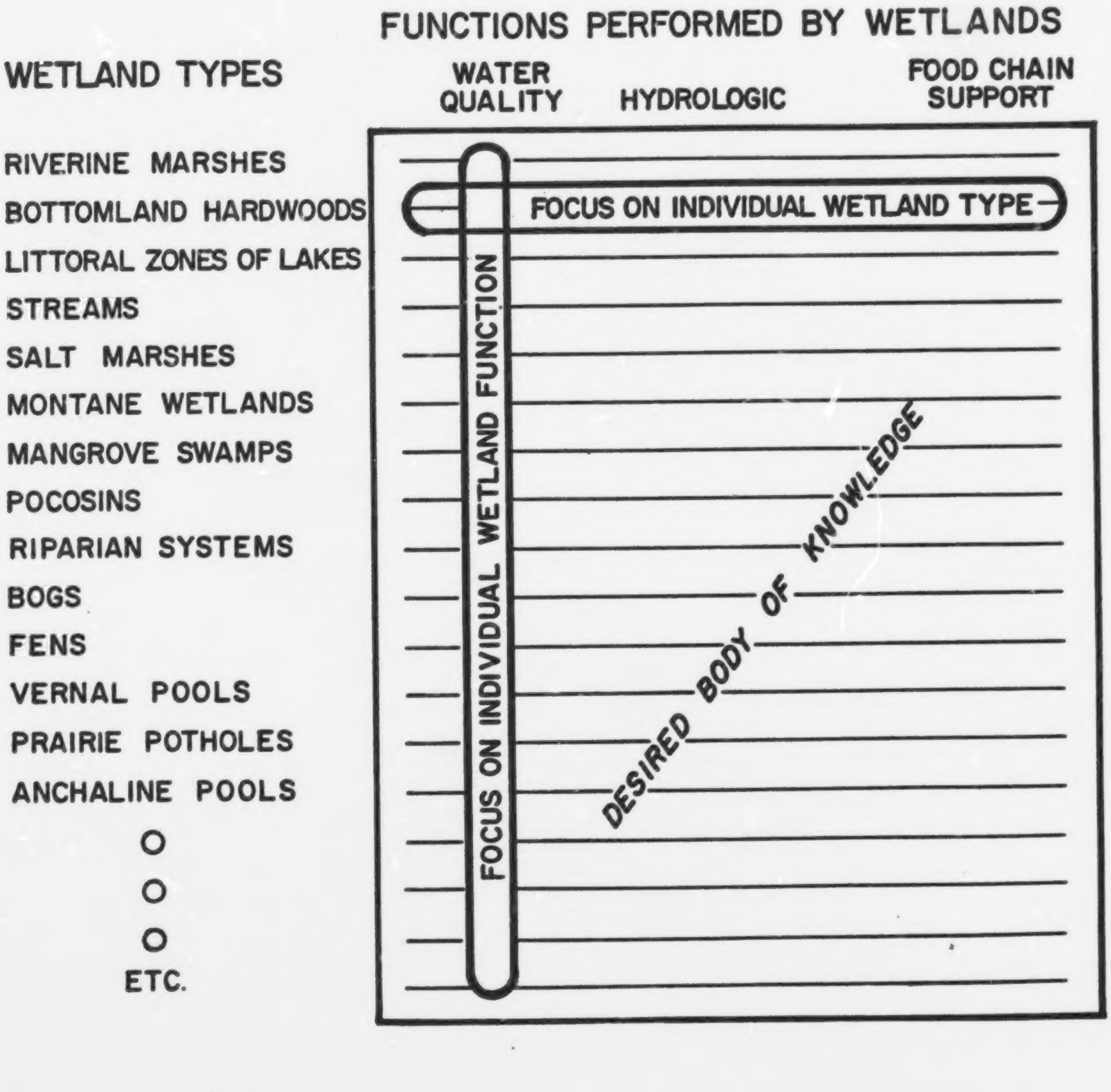
Through the planning process outlined in Section I, priorities for EPA's role in wetland research were set in relation to the plans of other Federal agencies. In order to achieve the full range of desired knowledge (i.e., quantification of all functions for all wetland types), it is possible to begin with a focus on either a major wetland type (wherein all functions would be investigated in detail at representative sites) or on one major function (with comparative assessment of that function over many wetland types) (Figure 1). Either approach provides a starting point upon which research efforts can expand to include all functions and all wetlands.

I.B.3.a. Water quality

It is recommended that EPA primarily focus on the water quality function, making a comparative assessment over many wetland types. EPA's research with toxic materials and pesticides and its excellent laboratory facilities make this agency well suited for such an emphasis. This goal also complements the work of several other agencies on wetland functions. As one example, SCS is concerned with water quality, but interest is focused on agricultural runoff. For another example, COE is planning to focus on all three wetland functions in bottomland hardwoods. However, COE researchers will assess water quality functions only within their selected bottomland hardwood site.

It is recommended that EPA develop some of its research at the COE site. The detailed long-term studies that COE is planning to initiate in FY'86 will provide an excellent backdrop for manipulative experiments. EPA should fund experiments on the ability of wetlands to retain or transform organic compounds, heavy metals and nutrients. The experiments of

Figure 1. The body of knowledge required to quantify wetland functions at any one point in time includes an understanding of their role in altering water quality, their influence on hydrology and their support of food chains. Two different approaches are possible to develop the desired information: a focus on individual wetland type with study of all wetland functions, or a focus on one wetland function compared over a wide variety of wetlands types.


FUNCTIONS PERFORMED BY WETLANDS
WETLAND TYPES
WATER QUALITY
HYDROLOGIC
FOOD CHAIN SUPPORT
RIVERINE MARSHES
BOTTOMLAND HARDWOODS
LITTORAL ZONES OF LAKES
STREAMS
SALT MARSHES
MONTANE WETLANDS
MANGROVE SWAMPS
POCOSINS
RIPARIAN SYSTEMS
BOGS
FENS
VERNAL POOLS
PRAIRIE POTHOLES
ANCHALINE POOLS
O
O
O
ETC.
FOCUS ON INDIVIDUAL WETLAND TYPE
FOCUS ON INDIVIDUAL WETLAND FUNCTION
DESIRED BODY OF KNOWLEDGE

Brinson et al. (1984) on nutrient loading in an alluvial floodplain swamp demonstrate the feasibility and utility of such work (See review, Appendix IV). It may also be possible to perform some EPA-sponsored research at the Department of Energy's (DOE) Savannah River site.

Hydrologic functions are difficult to separate from water quality or food chain support functions of wetlands. In fact, it is impossible to evaluate the filtering or retention functions of a wetland without examining the wetland's hydrology, because water is the carrier. Hence, when reference is made to "water quality" functions, it is implied that the research include study of water flow over and through the wetland. Other hydrological functions, such as modification of ground water recharge and flood storage, are not recommended for specific study by EPA.

I.B.3.b. Cumulative impacts

A mechanism to assess and predict cumulative impacts on all major wetland functions for both fresh and saltwater systems is urgently needed by all staff involved in evaluating requests for 404 permits. The effect of one permitted project may go well beyond the site where activities occur. The effect may extend to the entire wetland, to the watershed where the wetland occurs, and the ecoregion(s) where the watershed occurs. Assessment of the cumulative impact of one or many small projects is perhaps the most difficult research objective recommended.

Methodology for cumulative impact assessment is in its infancy, and few reviews of procedures are available. Neither COE nor FWS has indicated an emphasis in this area of research. Witmer (Argonne Lab, pers. comm.) recently reviewed procedures for cumulative impact assessment and found the DOE procedure (cf. FERC notice in Federal Register 50, No. 16, p. 3385) for evaluating the impacts of multiple hydroelectric plants within watersheds to be the most promising.

It is recommended that EPA support research that will assist cumulative impact assessment on both the local (wetland) and regional (watershed and ecoregion) scales, with a specific research focus on the effects of granting individual 404 permits, and 404 general permits, if possible.

I.B.3.c. Mitigation

The process of mitigation is intended to hold stable the status of wetland functioning, so that there are no net losses of in-kind functions. Projects that would enhance, restore or create wetlnds to replace the values destroyed through the permitted project are being planned; others are in the process of implementation; still others have been in place for several years. Best known are the coastal salt marsh creation projects of COE, which have created habitat on dredge spoils. It is clear from their long-term dredge-material research program that artificial salt marshes can be created.

Information on inland wetlands is less well documented. Efforts to create emergent freshwater marshes have been the most successful, while wetlands with woody or submersed aquatic vegetation have been more difficult (Garbish, Environmental Concern, Inc., pers. comm.). Commercial nurseries are beginning to stock some of the woody, wetland species. So, the methodology is developing. However, there are controversies over the value of altered ecosystems (especially impounded wetlands) and questions of how to restore various systems, e.g., bottomland hardwoods that have been cleared for agriculture. Another set of problems arise when hundreds of acres of wetlands must be created or restored, e.g., how to collect and handle of the amount of plant material necessary.

While information is limited on the techniques of restoring inland wetlands and on the likelihood of success for various mitigation projects in both fresh and saltwater systems, there are opportunities to realize large gains by reviewing past efforts and integrating manipulative experiments into newly permitted mitigation projects. These research efforts will complement well the technical transfer functions of COE and others (e.g., Association of State Wetland Managers' plans for a workshop on mitigation). Most important, it will compile information the Regions desperately need.

I.B.4. Recommendations for the roles of other Agencies

Hydrologic functions. COE has a history of involvement in flood- and ground-water-related projects, and the U.S. Geological Survey (USGS) is responsible for monitoring selected hydrologic features throughout the nation. FHWA has some concerns with runoff, because of the effect of highways on surface water flows. DOE has a site-specific interest in the hydrology of its bottomland hardwood wetlands at the Savannah River facility. EPA will study hydrologic functions as they relate to the water quality research proposed in Section II.A.

Food chain support functions. Habitat values, or support of food chains, are generally regarded as the responsibility of FWS, because of its involvement in habitat evaluation procedures, its role in developing wetland data bases, and its National Wetland Inventory. COE will be assessing the relationships between wetland habitat and wetland species in their bottomland hardwoods study. EPA's role in examining food chain support functions should come primarily in the assessment of cumulative impacts and mitigation projects, as discussed below.

Ecosystem syntheses. EPA's role in quantifying wetland functions within any specific ecosystem type should be limited to the support of data syntheses. COE and DOE will have the lead in examining bottomland hardwood forests, as indicated above. EPA should encourage the preparation of "Community Profiles" for freshwater wetlands. FWS has an excellent publication program that has focused on coastal wetlands; these summarize existing data for a management-oriented audience. It is recommended that such data syntheses be developed for target wetland types that have been identified as having high priority by EPA Regional Offices (See Appendix I). Rather than attempting to duplicate the successful Community Profile effort of FWS, EPA should assist it with pass-through funding.

Wetland delineation research. Wetland delineation methods have been developed by COE, and FWS has proposed to implement boundary determinations through a range of field studies (See Appendix II). In EPA's former wetland research program, vegetation-based studies were performed on Pacific coastal wetlands. While it is important for EPA to review boundary determinations, further research in this area is not recommended. Rather, EPA should retain the capability to respond to any controversies that develop through short-term, site-specific studies, as the need arises. In particular, Regions 7 and 9 have expressed a need for wetland delineation criteria for their ephemeral wetlands. Furthermore, EPA has been developing a wetland delineation methodology (Sipple, EPA, pers. comm.). It is recommended that COE and EPA continue this effort jointly to establish a mutually acceptable methodology.

Wetland value assessment. The development of methods to assess wetland values has been the focus of several research efforts, and several streamlining procedures are in progress. As mentioned above, COE is computerizing the FHWA Technique. It is recommended that EPA not spend further research funds in this area to develop new assessment methodology. Rather, the entire research program is structured to help provide the information necessary for refining the FHWA Technique. The data acquired under the water quality section will feed directly into the assessment strategy. The experimental component of the mitigation research will fill gaps in the assessment of hydrologic and food chain support functions. The cumulative impact models would allow the analysis of functions to go beyond the assessment of single sites.

I.B.5. How do the efforts of EPA, COE, and FWS fit together to form an integrated, comprehensive program of wetland research?

It is recommended that EPA's wetland research program focus on three areas:

* Water quality functions (and associated hydrology) of a wide variety of wetland types,
* Cumulative impact assessment, and
* Mitigation.

Research performed in these three areas will also provide some information on hydrologic and food chain support functions. New data will be made available for ecosystem syntheses that bring together the state of knowledge for individual wetland types. Thus, EPA's research program will focus on three areas but include a broader range of necessary information (Figure 2).

How this fits into an overall Federal wetland research program is depicted in Figure 3, wherein three dots indicates major emphasis (within that agency's budget), and one dot indicates some effort. The COE's emphasis is on bottomland hardwoods and assessment methodology; the FWS emphasis is on food chain support functions. All indications are relative, and all were obtained from discussions at the September 18, 1985, meeting of the Interagency Wetland Coordinating Committee.

I.B.6. How do the three areas of research recommended for EPA compare scientifically?

The science of water quality functions, cumulative impact assessment and mitigation differs in current conceptual status, availability of experimental procedures, and the probability of performing successful research. However, they are similar in that the value of an increment of knowledge in all three areas is high. These comparisons are graphed conceptually in Figure 4 on a relative scale.

For water quality research the state of knowledge is high relative to that for cumulative impact assessment and mitigation. Experimental procedures for water quality research are readily available, although standardization is needed. The probability of success in the research proposed here is high. The research program would substantially improve EPA's water quality modelling ability, so that predictions of change following 404 permit approval would be developed for individual

Figure 2. To develop the body of knowledge needed to identify the cumulative impacts of wetland alteration requires that past losses and future gains be tracked. These losses and gains can then be related to changes in the water quality (WQ), hydrologic (H) and food chain support (FCS) functions.

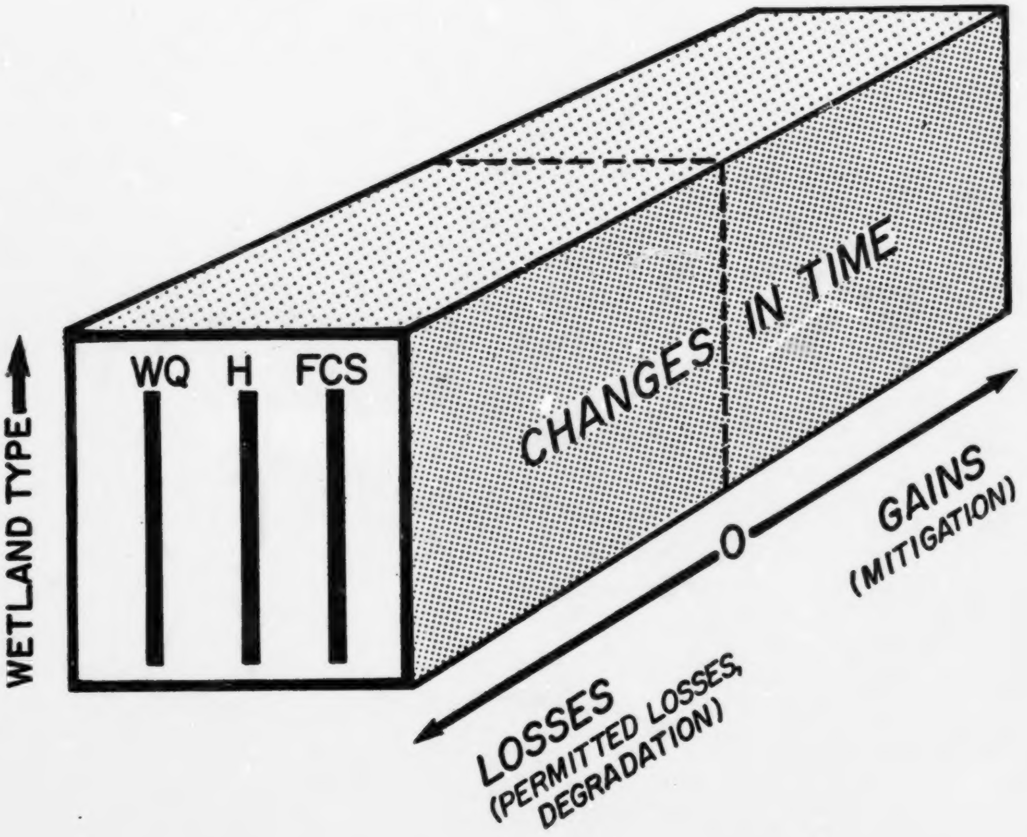
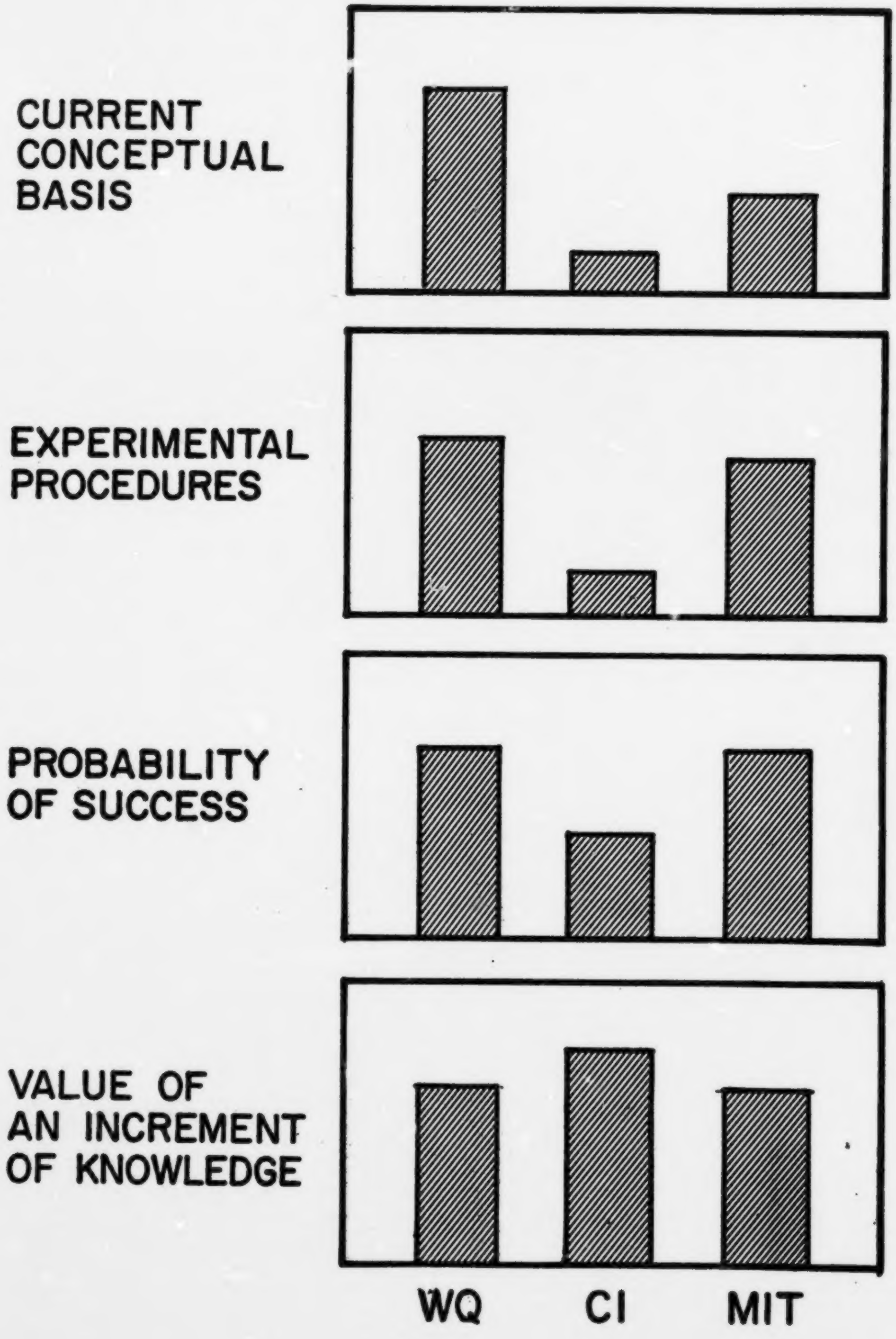

WETLAND TYPE
WQ
H
FCS
CHANGES IN TIME
GAINS
(MITIGATION)
0
LOSSES
(PERMITTED LOSSES,
DEGRADATION)

Figure 3. Integrated program of research presented as a matrix of the research interests of the Federal agencies and overall information needs.

WETLAND RESEARCH NEEDS	FEDERAL AGENCIES INVOLVED IN WETLAND RESEARCH			
	EPA	COE	FWS	OTHER
QUANTIFY WETLAND FUNCTIONS				
WATER QUALITY (and associated hydrology)	●●●	●●		SCS, DOE
HYDROLOGIC (e.g., flood storage, ground water recharge)	●	●●		USGS, DOE, FHWA
FOOD CHAIN SUPPORT/HABITAT	●	●●	●●●	DOE
DEVELOP ECOSYSTEM SYNTHESES (community profiles)	●		●	
ECOSYSTEM STUDIES (bottomland hardwood studies)	●	●●●		DOE-SREL
ASSESS CUMULATIVE IMPACTS	●●●		●	
ASSESS MITIGATION PLANS AND PROJECTS	●●●	●	●	
WETLAND DELINEATION (methods for detecting wetland boundaries)	●	●	●	
VALUE ASSESSMENT METHODOLOGY (revising or replacing existing procedures)	●	●●●	●	FHWA

Figure 4. Comparison of water quality (WQ), cumulative impacts (CI), and mitigation (MIT) on a relative scale.



wetlands and substantial progress would be made in modeling the cumulative impacts on water quality within watersheds and possibly ecoregions.

For cumulative impact assessment, the state of knowledge is extremely limited, and little is known about how to proceed; thus success cannot be guaranteed. Careful planning of future research is required. It is a new and important field, however, and the value of an increment of knowledge is extremely high.

For mitigation, there is information available, but much of it is not available to 404 coordinators or associated staff. Approaches to be used are those of ecological research, which has a rich set of study methods. Substantial gains could be made in this component of the research program through review of past mitigation efforts and integration of long-term experiments into proposed mitigation projects. The need to improve mitigation projects so they enhance, restore and create inland wetlands is high.

II. THE RESEARCH PLAN

II.A. WATER QUALITY AND RELATED HYDROLOGIC FUNCTIONS

Goals:

To quantify the water quality functions of wetlands; to model the aggregated role of wetlands in altering the quality of water in receiving water (at the wetland, watershed, and ecoregion scale); to design simple decision criteria for evaluation of water quality functions, and to assess the effects of cumulative wetland losses on the quality of water in receiving water (at the wetland, watershed and ecoregion scale).

II.A.1. Background and rationale

To insure that regulatory decisions are sound, EPA must have adequate understanding of the structure and functions of wetland systems and the impacts of perturbations to them from regulated activities (Meagher 1985). Wetlands function to alter water quality (by removing, releasing or transforming nutrients, anthropogenic substances, and sediments), modify hydrology (by slowing flood flows and reducing erosion) and provide habitat for support of a diverse food chain. The roles of freshwater wetlands in flood-flow hydrologic buffering and as sedimentation basins are well documented. Their importance as fish and bird habitats is widely recognized. Water quality functions are the most poorly understood of the wetland functions and are not the primary focus of any other agency's research program.

It is recommended that EPA's research program focus on water quality, because the need is strong and because EPA has considerable expertise and facilities for water quality research. "Water quality function" is defined here as the uptake, transformation, or addition of materials as water flows through the wetland. The function has positive value: 1) when there is a net removal of materials that would cause negative impacts downstream and/or 2) when the materials are transformed into substances that do not cause negative impacts downstream.

It is widely assumed that wetlands filter sediments, nutrients, and anthropogenic substances from flowing waters. However, the documentation is strongest only for uptake of nitrogen and phosphorus. Even for these two nutrients, the rates are variable, partially because few studies have performed complete analyses of inputs and outputs. Lack of calibration and standardization of methods have made the comparison of filtering rates uncertain (Nixon and Lee 1985). Measured rates are also variable because many processes effect transformation and removal of nutrients in wetland systems--sedimentation, conversion to more refractory chemical forms, sorption onto soil particles, uptake and internal cycling by microbes and higher plants, and denitrification. The rate of each process depends upon factors such as nature of the soil (organic vs mineral), pH, redox potential, flooding regime, vegetation, and nutrient loading rate (e.g., Nicholls 1983, Richardson 1985, Brinson, et al. 1981, 1984; Kuenzler, et al. 1980, Ewel and Bayley 1978, Reddy 1984). And finally, the long-term ability of wetlands to reduce nitrogen and phosphorus concentrations, i.e., the cumulative uptake capability, is also unknown.

For metals and organic chemicals, the data base is minimal (Giblin 1982, Dickerman et al. 1985). Not known are: which materials are likely to be stored or transformed, the rates at which accumulation and transformation proceed, what controls those rates, and what potential different wetlands have for long-term uptake, given continued loading.

In the process of performing water quality functions, wetlands are affected by the materials they accumulate. In isolated areas, the effects of low-level inputs may be minor, but in wetlands downstream of urban or agricultural areas, there may be cumulative impacts of high-concentration loadings. In many areas, wetlands will receive several types of materials at high concentration. Water quality functions should be expected to change as each alteration occurs. The scientific literature indicates that these effects are not simply additive. According to Giblin (1982) one type of disturbance (e.g., nutrient influxes) can enhance the impact of another (e.g., solubility of heavy metals) indirectly by altering vegetation and changing soil redox conditions. Few studies of such interactions are available, and the need to explore them is clear for wetlands subject to multiple loadings.

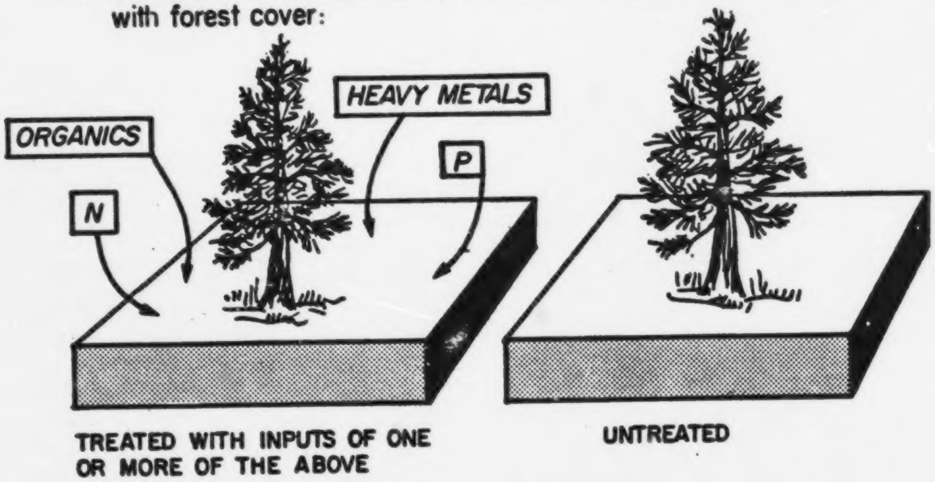
Data from long-term research programs at selected sites (e.g., studies of wastewater wetlands) can help to determine the impacts of several alterations on water-quality functions within a wetland. Long-term ecological research sites funded by NSF and the Smithsonian Institution should provide some of the information needed to understand cumulative impacts on a single wetland. Assuming that additional long-term, site-specific research programs will not fit within EPA's budget, an alternative approach appears prudent to maximize information gain.

Water quality improvement functions do not occur independently of hydrologic or food chain support functions. The dynamics of nutrients, toxins, or sediments can hardly be evaluated without considering hydrology. It is, however, possible to initiate a research program on water quality improvement by focusing on rates of accumulation and transformation. Hydrologic work can be limited to specific measurements. Similarly, the accumulation of toxins by plants and animals cannot be examined without acknowledging the impact on the entire food web. However, analyses of biota can be restricted to soil microbes and shallow rooted vegetation.

It is proposed that EPA begin with an experimental program using a broad range of wetland types. To obtain results that can be extrapolated to larger ecological units, it is recommended that the basic experimental units be on the "mesocosm," rather than "microcosm" scale. Field manipulations should be done on the scale of several square meters, with artifical experimental units on a comparable scale (Figure 5). Using this size of experimental systems should have two advantages: 1) samples can be collected over a long period of time without destroying the areas treated, and 2) an array of wetland species can be accommodated, approximating those in nature. At the same time, using mesocosms will likely increase variability between experimental units, therefore, careful replication will be essential. Microcosms, such as typical laboratory aquaria, may be appropriate in some cases, e.g., microbiological work. However, wherever possible, the use of larger systems than have previously been employed for experimental work is suggested.

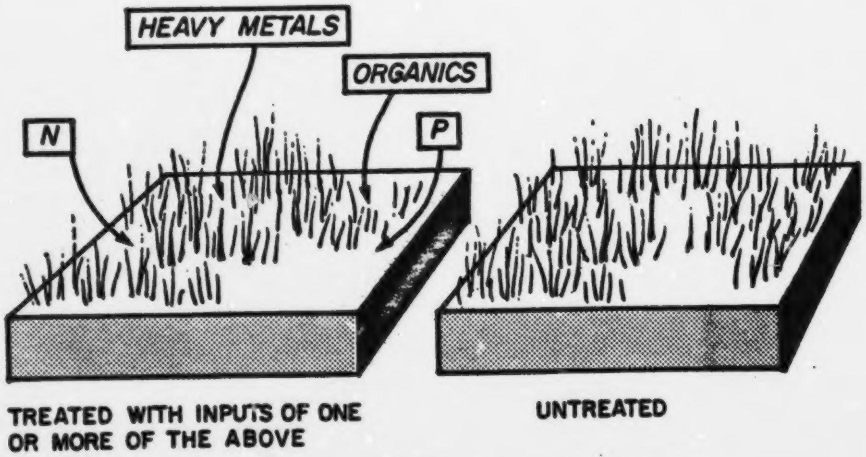
Figure 5. Research on water qualitly functions should utilize manipulative experiments in mesocosm-size areas. For forested wetlands experiments must be done in situ ; for non-forested wetlands it will be possible to construct artificial mesocosms and work with a variety of wetland types at selected mesocosm facilities. Experiments would manipulate the type and rates of loadings and assess the fate of the substances.

A. Mesocosm-scale field experiments are required for wetlands with forest cover:


HEAVY METALS
ORGANICS
P
N
TREATED WITH INPUTS OF ONE OR MORE OF THE ABOVE
UNTREATED

IN SITU FIELD EXPERIMENTS

B. Mesocosms can be developed for wetlands that are dominated by herbaceous vegetation:


HEAVY METALS
ORGANICS
N
P
TREATED WITH INPUTS OF ONE OR MORE OF THE ABOVE
UNTREATED

ARTIFICIAL MESOCOSM EXPERIMENTS

II.A.2. State of knowledge

Nixon and Lee (1985) provided an extensive, region-by-region review of nutrient and metal uptake functions of wetlands for COE. Their overall conclusion was that "credible quantitative assessment" of the role of wetlands in water quality cannot now be done because of insufficient data. Research in this area is only 5-10 years old. No single region nor wetland type is adequately understood.

To fill the information gaps Nixon and Lee (1985) recommended a two-fold approach. Long-term field studies, conducted in combination with experimental studies using wetland mesocosms, are needed to develop mass balances (i.e. budgets of carbon, nutrients, heavy metals, other pollutants) at selected sites. The need to calibrate methods prior to comparative experimentation was emphasized.

Dickerman et al. (1985) reviewed the ability of wetlands to take up nitrogen, phosphorus, and pesticides from agricultural runoff. Their conclusions (Appendix III) are that wetlands are effective at retaining and transforming these materials, but that rates differ with a wide variety of controlling variables. They recommend developing water quality models that have a hydrologic component as the core, with individual process submodels to determine rates of retention of different materials. They acknowledge that only the core model can be constructed with the existing knowledge of wetland water quality functions.

Richardson (In press) reviewed the fluxes, transformations and storage of nitrogen, phosphorus, and carbon in freshwater wetlands. He states, "the data...suggest that wetlands are not efficient in terms of being large annual nutrient sinks or filters." Their large stores of N, P, K, and C have accumulated over centuries. However, they do function as "transformers" by converting nutrients into a less available form. Wetlands are significant in transforming inorganic nitrogen to nitrogen gas and may be important in sulphur transformation. However, Richardson (pers. comm.) concludes that biogeochemical data are inadequate to make valid comparisons of different wetland types or ascertain the "true value" of many wetland ecosystems.

In another paper (Richardson 1985), phosphorus retention is suggested to be less efficient in wetland than in terrestrial ecosystems. Wetlands used for wastewater discharge may show high rates of phosphorus removal initially, however large exports can be expected after a few years. Thus, phosphorus removal efficiency may be a function of cumulative phosphate inputs, and the threshold for retention may be exceeded in a short time if a wetland experiences excessive loading. Burns and Taylor (1979), however, make the point that wetlands exporting large quantities of phosphorus may do so largely in the organic form, such that the likelihood of a negative impact (stimulation of an algal bloom) downstream is still reduced. Again, the wetland is seen to function as a transformer in improving water quality.

The factors controlling nutrient retention and transformation vary considerably between wetlands and through time. Using microcosm experiments, Richardson (1985) showed that phosphate adsorption differed substantially for five different wetland soils. The varying uptake rates positively correlated with the concentration of soil-extractable aluminum. Thus, it is important to evaluate retention rates over a range of loading rates and sediment types. Moreover, his work showed that experimental microcosms can help greatly to understand rates of and controls on retention.

The complexity of controls on retention rates has been documented by Giblin (1982). Her work with heavy metals in salt marsh sediments showed that retention of iron, zinc, copper, and cadmium can be reduced by adding nutrients. Nutrient additions increased primary production. Higher plant growth rates tranferred more oxygen to the soils via the roots. Increased oxidation decreased the concentration of sulfides, and that increased the solubility of metals in the pore water. Thus, there are likely to be interactive effects among materials that are added to wetland soils, and multi-factor experiments are needed.

There are few mass balance studies for heavy metals. Giblin's review (1982) concluded that retention rates vary for different metals and different wetlands. Retention rates were found to be highest for lead if loading rates were low, while most metals, such as zinc and cadmium, may pass through the ecosystem. She concluded that wetlands are good sinks for some metals but that their retention capacity may vary through time. Research needs include long-term studies, examination of interactive effects, and detailed study of wetland hydrology and pore water chemistry.

Overall, the water quality functions of freshwater wetlands are poorly understood. Nutrient detention and transformation roles have been used for control actions at the state level. The ability of wetlands to reduce organic toxicant and heavy metal loadings is widely assumed. However, none of the functions has been comprehensively quantified.

II.A.3. Planning a coordinated approach

The proposed water quality research has been designed as a coordinated experimental approach with three basic objectives.

First, rate functions and the factors influencing them will be determined for organic chemicals, heavy metals and, as necessary, nutrients. Second, interactions between these substances and the factors influencing them will be identified. Since the wetlands are affected by the substances they accumulate, proposed research includes study of biological responses to toxicant addition. Third, the rate functions of individual wetlands will be combined into models that predict the effect of wetlands on the quality of receiving water on the scale of a watershed and possibly ecoregion. At the same time, simple decision criteria to evaluate the water quality functions of individual wetlands will be designed.

A meeting of scientists should be convened to select the wetland types with highest priority for study of water quality functions and with highest suitability for experimentation. This group should also include experts in wetland models. The formulation of models (conceptual and literature based) should precede and guide the research. It will be important to coordinate the modelling effort with the research approach. The Regional Offices should be consulted as part of this process. The participants should then develop and test standard methods for investigation. This assumes that more than one lab will be involved in research, and that there is a need to test the reliability of methods being used in more than one type of wetlands. EPA should select the labs most suited to perform the manipulative research. The operation of the Delta Waterfowl and Wetland Research Station in Delta, Manitoba, Canada, may serve as a model. It is the site of a long-term, ambitious study of the effects of changing hydrological regimes on the rates of mineral cycling within freshwater marshes (Murkin et al. 1985).

There are several candidate labs that could carry out this research. For example, the Monticello streams at the Duluth EPA Lab would be appropriate mesocosms for work of this type with northern wetlands. Outside EPA, mesocosm facilities exist at Cornell University (experimental ponds), Michigan State University (large experimental wetlands) and other locations, so that proposals could be solicited for additional regions. Before the organizational meeting of scientists is convened EPA should identify all of the sites where long-term and/or manipulative wetlands research is being conducted. An assessment of the status of wetland modelling should also be done. Some of the questions to be answered are who is doing wetland models at this time, what success have they had, and how can ongoing efforts be expanded or redirected to include EPA objectives. This early effort would lay the groundwork for the planning session.

Field or in situ experiments. It is recommended that specific experiments with pesticide, heavy metal, and nutrient additions be carried out in the COE's wetland research site. COE will have selected a large bottomland hardwood site in the Mississippi River floodplain for long-term ecological research by the end of 1985. Preliminary discussions indicate that the site will be well over 100 acres, so that small plots ("mesocosm scale") could be manipulated in replicate without disrupting COE studies. There may also be opportunity to develop experiments at DOE's Savannah River bottomland hardwood forest.

Specific field experiments should manipulate influxes (i.e., different loadings) of organic chemicals, heavy metals, and nutrients (especially nitrogen and phosphorus). Brinson, et al. (1984) have shown that such field experiments are effective for testing specific management related hypotheses, and for assessing the proportion of added nitrogen and phosphorus that accumulates in or was transformed by the wetland. (See review of this work in Appendix IV). Furthermore, this work could be expanded to include wetlands used for wastewater treatment.

A subset of the same experiments should then be carried out in artificial mesocosms utilizing sediments from the same field site. This approach has been proven effective on a smaller scale. A detailed evaluation of microcosms documented their considerable utility in solving ecological problems in aquatic, as well as terrestrial, ecosystems (Giesy 1980). Past comparisons of sediment-water interactions (Kelly 1984) indicate that artificial microcosms can mimic field conditions for relatively long periods of time (at least 1-2 months). Therefore, comparisons of the laboratory and field studies in the bottomland hardwood site could justify use of only laboratory studies.

Artificial mesocosm experiments. Artificial wetlands in mesocosms should be used to analyze the uptake, accumulation, and chemical transformation of organic chemicals, heavy metals, and nutrients. Comparative studies should be conducted in northern and in southern climates, using a wide range of wetland types, identical experimental set-ups, and calibrated methods. These experiments should provide two types of results: 1) quantification of uptake and transformation rates under different environmental conditions and 2) understanding of the factors controlling those rates. For at least two natural wetlands near each facility, there should be a subset of field experiments to compare in situ and artificial mesocosm results.

Rates of accumulation in soils and plant tissues and any transformations (e.g., denitrification) should be measured under controlled environmental conditions that are appropriate for the region. That is, temperatures and water circulation rates should fall within the normal range for each wetland.

Before funding large manipulation projects, EPA should initially fund one study to "work out the bugs". Like any other project, there will be problems and it will be most efficient to identify and solve them on a smaller scale. In addition, it will be essential to know how mesocosms compare to natural systems and a small project could provide some insight. This work would best be done by a group that has a lot of data on a natural system and would be in a position to move rapidly to initiate appropriate experiments in mesocosms.

II.A.4. Rate functions

II.A.4.a. Objectives

To determine rates of retention and/or chemical transformation of organic chemicals, heavy metals and nutrients entering wetlands; to identify the factors that influence these rates; and to assess the possible impacts of these substances on the wetland.

II.A.4.b. Rationale

Quantification of the rates of retention and removal will lead directly to capability for wetland evaluation and cumulative impact assessment by EPA personnel. Identification of impacts on the wetland will further augment the process.

II.A.4.c. Research approach

Manipulative experiments, where selected materials are added to wetland systems in known amounts and their fates observed under varied conditions, are recommended over descriptive studies of natural ecosystems. The rationale for this approach is two-fold. First, it will be possible to examine functions over a variety of environmental conditions within a short time-frame, and second, it will be possible to test cause-effect relationships. Thus, the research should rapidly identify minimum and maximum rates (of uptake, transformation, release) and proceed toward an understanding of the factors that influence those rates.

The microbial community is undoubtedly the major component of the biota involved in retention and transformation of substances within wetlands. Therefore, detailed study of microbiological processes involved in retention and transformations is needed. Experiments should focus on the relationship between physical factors and the rate at which the microbial community functions.

Artificial wetlands with low, medium, and high retention rates in a full range of mesocosms will be selected for study of components responsible for uptake and microbiological processes affecting retention. Artificial wetlands with low, medium, and high transformation rates (e.g., breakdown of organic compounds, denitrification) will be selected for study of biological components responsible for transformation and factors influencing breakdown rates.

II.A.4.d. Time line and cost to produce techniques for evaluating the role of individual wetlands in altering receiving water quality on a watershed basis

WORK/PRODUCTS	COST PER YEAR OF PROGRAM (K/year) 1	2	3	4	5	6	7	TOTALS	
Plan and construct artificial and *in situ* mesocosms for experimental work (★ indicates that these mesocosms are required for the work/product)									
COE bottomland hardwood site	75							75	550
Two additional *in situ* and two artificial mesocosms	25	450						475	
NUTRIENTS									
See Model Section II.A.6. for provisional models which will contribute to the following products.									
★ Validate models and collect additional data as necessary									
COE bottomland hardwood site		100	100					200	1050
Two additional *in situ* and two artificial mesocosms			50	400	400			850	
ORGANICS									
See Model Section II.A.6. for conceptual models which will contribute to the following products.									
★ Collect data on uptake, transformation and release of organic chemicals by different wetland types									
COE bottomland hardwood site		200	200					500	2050
Two additional *in situ* and two artificial mesocosms		150	50	500	300			1000	
★ Validate models (see Section II.A.6.)					250	300		550	
METALS									
See Model Section II.A.6. for conceptual models which will contribute to the following products.									
★ Collect data on uptake, transformation and release of metal chemicals by different wetland types									
COE bottomland hardwood site		75	100					175	925
Two additional *in situ* and two artificial mesocosms			50	200	200			450	
★ Validate models (see Section II.A.6.)					150	150		300	

II.A.5. Interactions among nutrients, organics and heavy metals, and their impacts on the water quality function

II.A.5.a. Objectives

To identify the interactions (synergistic, antagonistic relationships) between elements or compounds entering wetlands and the factors controlling those processes; and

To assess the impacts of elements or compounds entering wetlands on the wetlands.

II.A.5.b. Rationale

In many areas, wetlands receive several types of materials, and it is unlikely that their effects are independent. As discussed earlier, nutrient inputs can affect the ability of a wetland to remove heavy metals from water. Therefore, accurate prediction of water quality function of wetlands requires that the complex relationships among organic chemicals, heavy metals, and nutrients be known. Concurrently, these results will be incorporated into water quality models that will be used to evaluate 404 permit requests.

At the time that wetlands accumulate or transform materials such as organic chemicals, those materials can alter the wetland's ability to alter water quality. The impact of individual substances on wetlands will be assessed in the mesocosm experiments of Section II.A.4.d.; the impact of multiple imputs will be assessed in the interaction experiments (Section II.A.5.c.). Thus, the research will involve additional measurements within experimental treatments established for the purpose of measuring uptake and transformation rates.

II.A.5.c. Research approach

The research approach outlined in Sections II.A.3.b. will be expanded to include treatments that add two or more materials simultaneously to mesocosm units. Uptake rates will be assessed as in previous experiments.

Impacts of single and multiple loadings will be determined by assessing the growth rates of vegetation. The determination of impacts on wetlands will be used to predict the long-term ability of wetlands to continue their water quality functions. Results from this research will feed directly into water quality models.

II.A.5.d. Time line and cost to identify the interactions among nutrients, heavy metals and organics, and assess their impacts on the water quality function of the wetland.

COST PER YEAR OF PROGRAM (K/year)

	WORK/PRODUCTS	1	2	3	4	5	6	7	TOTALS	
	ORGANICS									
	Determine residue analysis for selected organic chemicals			150					150	1050
★	Evaluation of interactions between organic chemicals and nutrients for use in water quality models					175	175		350	
★	Impact assessment for effects of organic chemicals on wetland vegetation				200	200	150		550	
	METALS									
	Determine residue analysis for selected metals				75				75	975
★	Evaluation of interactions between heavy metals, and nutrients and organic chemicals for use in water quality models				150	150	150		450	
★	Impact assessment for effects of heavy metals on wetlands vegetation				200	200	50		450	

II.A.6. Models and simple decision criteria

II.A.6.a. Objectives

To model the water quality function of freshwater wetlands at the wetland, watershed and ecoregion scales; design simple decision criteria for evaluating water quality functions of individual wetlands and the cumulative water quality function of all wetlands within a watershed and ecoregion (Figure 6).

II.A.6.b. Rationale

Models provide a vehicle to present scientific information in a format that will be useful to decision makers. Only by the application of process-based modeling can knowledge gained from the study of one ecosystem be extrapolated to others. Moreover, an interactive computer code can be an objective tool for risk/benefit evaluation. For example, the EXAMS2 code, which is used in the EPA Office of Pesticides, predicts the fate of a chemical in a particular aquatic scenario (Burns, 1985).

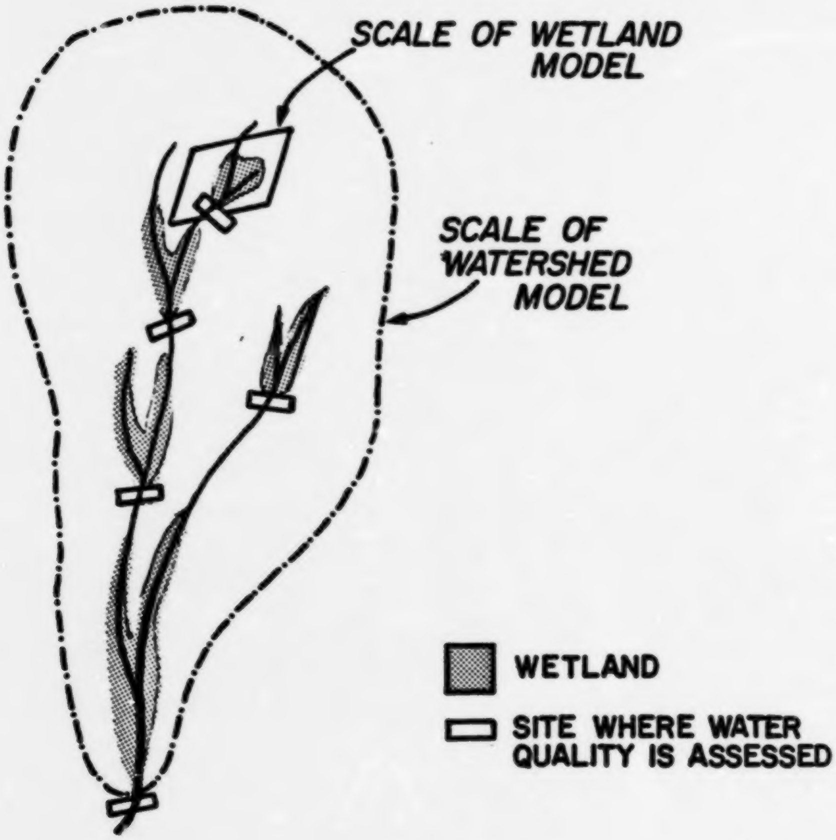
Experience with the production of such tools has proven their feasibility and has promoted contributing research. As summarized by Dickerman et al. (1985), there is the capability to model hydrologic processes, but not the associated retention/transformation functions of wetlands. The "core" of the water quality models can be developed at once. With the accumulation of information from the mesocosm experiments, it will be possible to expand the modeling effort to include complex water quality functions.

II.A.6.c. Research approach

Process modeling begins from a base of fundamental understanding of the kinetics of water quality processes. These kinetics are functions of environmental forces, including both internally controlled system resources (e.g., dissolved oxygen and pH) and the externally imposed system environment (e.g., site geology and regional climate). Given valid functional expressions of process dynamics, extrapolation among systems can, at least in principle, be reduced to characterization of their relevant differences in driving forces.

This approach has in fact been very successful in practical water quality modeling. In consequence, there is a significant background of completed water quality computer codes that could be parasitized for components for wetland models. In addition, there is a significant literature on modeling wetlands per se, to the extent that it has engendered specific review articles.

Figure 6. The role of wetlands in altering water quality can be assessed locally or for the watershed as a whole. Models must begin with an understanding of local effects and then be combined to assess watershed level effects.


SCALE OF WETLAND MODEL
SCALE OF WATERSHED MODEL
WETLAND
SITE WHERE WATER QUALITY IS ASSESSED

Thus, a legitimate general model of water quality functions of wetlands could be constructed at this time.

Computer codes designed to model the water quality of entire watersheds are also available. These could be derived from a thorough review and synthesis of the behavior of process-based ecosystem models. Moreover, the codes could be used to evaluate the water quality consequences of the progressive destruction of wetlands within a watershed. In such models, the functions of each type of wetland would probably have to be described in rather simple terms, to avoid unmanagable complexity. Useful results from this "black-box" type of evaluation could be available in the near-term.

Therefore, despite present gaps in the knowledge, model development can proceed at the individual wetland and watershed levels. Effective provisional codes can be constructed for near-term testing and wetland evaluation. These codes could then be updated as new information becomes available from the field and laboratory studies.

At the next higher level of resolution the goal would be to model the water quality function of wetlands within an ecoregion. However, this increase in scale also increases the complexity of the model. Therefore, it is recommended that the feasibility of construction ecoregion scale models be explored before funds are committed to construct the model.

The modeling effort should be used to direct the research effort. Planning should procede as indicated by the gaps in the literature based model for nutrients and by the conceptual model developed for organic compounds and heavy metals.

Concurrent with model development, simple criteria for assessing the significance of different levels of water quality improvement can be developed. The procedure will utilize wetland rate models to predict the per-acre value of uptake/transformation functions. Then, criteria will be designed based on the comparison of a wide range of wetland types. This procedure will fit directly into wetland assessment strategies that ask whether the wetland has a high, medium, or low value for individual functions.

"Significance" would be determined from the comparative rates of uptake/transformation and/or the relative proportion of watershed discharge influenced by that wetland. In other words, the value of the wetland in improving water quality derives from 1) the rate of uptake or transformation per unit area and 2) the volume of improved water discharged from the ecosystem. Wetlands with either a high rate or a high discharge would be ranked significant in that water quality function.

Setting the criteria for high vs. low uptake/transformation should be done with as broad a data base as possible. The experimental program of Section II.A.4. will add to existing values in the literature. Frequency histograms of all known rates for each material uptake/transformation will allow determination of low, medium, and high values, using measures of central tendency.

For wetlands with relatively low rates of uptake, significant water quality function is still likely if the wetland influences high volumes of water. And the cumulative value of several water quality functions may be high even when individual rates and flows are low. The modeling effort should be designed to evaluate wetlands for individual uptake/transformation rates, volume of flow influenced, and cumulative water quality functions.

II.A.6.d. Time line and cost to assess the aggregated role of wetlands in altering the quality of water in receiving water for selected ecoregions

	WORK/PRODUCTS	COST PER YEAR OF PROGRAM (K/year) 1	2	3	4	5	6	7	TOTALS	
	Report on feasibility of combining watershed data across entire ecoregions		75						75	475
	Report on assessment of importance of wetlands to receiving water quality for 2-4 ecoregions				100	250	50		400	
	NUTRIENTS									
	Provisional wetland rate model for uptake, transformation and release of N&P by different types of wetlands (based on literature)	50	125						175	750
	Provisional watershed model of effect of wetlands on N&P in receiving water (based on literature)	50	150						200	
★	Final wetland rate model for uptake, transformation and release of N&P by different wetland types (based on new data)					150			150	
★	Final watershed model of effect of wetlands and N&P in receiving water (based on new data)					150			150	
★	Determine simple decision criteria for evaluating water quality functions of individual wetlands						75		75	
	ORGANIC CHEMICALS									
	Conceptual wetland rate model for guiding research experiments.		50						50	775
★	Final wetland rate model on uptake, transformation and release of organic chemicals by wetland typec				200	200	100		500	
	Watershed models for organic chemicals by modifying nutrient watershed models as necessary				75	75			150	
★	Define simple decision criteria for evaluating water quality functions of individual wetlands.						75		75	
	METALS (all $ assume funding organic chemicals)									
	Conceptual wetland rate model for guiding research experiments.		50						50	450
★	Final wetland rate model on uptake, transformation and release of metals by wetland types				100	100	50		250	
	Watershed models for metals by modifying nutrient watershed models as necessary					50	25		75	
★	Define simple decision criteria for evaluating water quality functions of individual wetlands.						75		75	

II.B. CUMULATIVE IMPACT ASSESSMENT

Goal:

To assess the effect of cumulative impacts of wetland losses.

II.B.1. Background and rationale

Most of the permits reviewed by 404 personnel are for small projects that individually may not have major impacts on wetland functions but collectively may degrade and destroy wetland habitat and water quality functions. The significance of these numerous small projects can only be evaluated within the context of cumulative trends. Impacts of wetland alteration accumulate at the local scale, when several perturbations affect a single wetland, and at the regional scale, when several wetland areas are lost within a watershed or ecoregion. The problems are different for these two scales. Predicting the impact of cumulative losses on the water quality function is addressed in Section II.A. The following section refers only to the cumulative impacts of piecemeal loss on other wetland functions at the regional level.

The best evidence that cumulative losses have substantial negative impacts comes from areas where large percentages of wetland acreage have been destroyed and wetland species have become extinct or endangered with extinction. For example, enormous losses of wetland habitat have occurred in southern California, and habitat reduction has progressed to the point where several wetland-dependent species have become endangered with extinction. Reducing habitat acreage has had two major impacts on wetland ecosystems. 1) Space where natural populations can grow and reproduce has become more and more scarce; crowding into other habitats has become impossible; and subpopulations have died out. 2) Space that allows species to move into alternative wetland habitats in order to survive catastrophic events has been eliminated.

Without sufficient space, or with access to suitable space blocked by barriers (such as roadways that dissect wetlands), populations become extinct. In one California estuary cumulative disturbances drastically altered habitat for the endangered, light-footed clapper rail. Food, habitat and protection from predators declined and the population of birds (40 pairs) went extinct in 1984. This loss was one seventh of the state's total population.

Declining species abundances and shrinking geographic distributions can be used to indicate when the threshold for habitat loss has been reached. Wetland-dependent birds and rare wetland plants can be useful "red flags;" their declining abundance indicates excessive habitat loss. It is barely known how many other species (e.g., the hundreds of insects yet to be identified from these wetlands), or how many wetland functions, or what economic benefits are lost at the same time as habitat is destroyed. It is too late to identify them where most of the habitat is already gone, but there are still opportunities to identify and prevent such changes in other regions.

II.B.2. State of knowledge

Understanding the larger-scale impacts requires extrapolation of local impacts to watersheds and ecoregions. In order to predict cumulative impacts on the ability of wetlands to control sedimentation, extrapolation from known relationships appears feasible. The rates of erosion and/or accretion can be identified within small segments of a watershed. Erosion rates can be determined for individual soil types and slopes with similar types of agricultural disturbance and extrapolated to the entire watershed or ecoregion. An effort of this type is being carried out cooperatively between FWS and EPA; the Western Energy Land Use Team (WELUT) is developing impact models for a portion of the Mississippi Delta (Ischinger, USFWS WELUT, Ft. Collins, pers. comm.) with funding from EPA.

For many other wetland functions, cause-effect relationships are not well known. In many cases, the role of wetlands in the landscape may be a function of the mosaic of wetland types and specific environmental conditions, not just a function of wetland acreage. The whole may well exceed the sum of the parts. The wetland assessment strategy of Adamus (1983) assumes linear relationships between acreage of wetland and water quality or "filtering" functions. Yet, even within a long, narrow ("linear") watershed, the water quality functions may be enhanced as runoff proceeds downstream, if individual wetlands take up and release materials at different rates along the water course. Wetlands that function in nutrient uptake are not necessarily as efficient at heavy metal uptake. Because of the potential for interactions between nutrient loading and mobilization of heavy metals (Giblin 1982), the elimination of one wetland that is efficient at nutrient removal could reduce the ability of a downstream wetland to remove heavy metals.

The cumulative role of wetlands in changing downstream water quality is addressed in Section II.A.5. through watershed models. Models built to evaluate the collective water quality function of several wetlands also serve to evaluate the impact of removing wetlands or segments of wetlands on the quality of water flowing from the watershed.

Assessing cumulative impacts is a relatively new endeavor. Standard environmental assessment methods are not sufficient. Few methods have been used, validated and modified. Most often these methodologies are general guidelines or descriptive accounts of potential impacts that rely heavily on qualitative and subjective judgements (Witmer In press).

II.B.3. Document past losses

II.B.3.a. Objective

To determine the best strategy for summarizing cumulative acreage losses by wetland type, within wetlands, within watersheds, and within ecoregions. This will allow relationships between acreage losses and cumulative losses of wetland functions to be developed. Finally, the relationships between acreage and functions will be used to identify critical "break points" wherein future acreage losses would cause irreversible losses of functional values.

II.B.3.b. Rationale and background

Regional 404 personnel are very concerned about how to evaluate the many permit requests to alter small areas, where the individual project would have little impact but the collective effect of several such projects might be substantial. To make decisions on individual small-scale projects requires an assessment of how multiple permits would affect wetland functions. To do this with available data requires that past losses be linked to changes in functions. However, before a predictive capacity can be developed one must summarize information on past and present wetland loss, and, if possible anticipate future losses.

Curtis Richardson (pers. comm.) evaluated acreage losses permitted by COE over recent years within North Carolina. He analyzed not only the acreage losses, but also the location and type of wetland losses. While acreage losses were not great along the coast, most tracts where filling was permitted were linear, so that the miles of coastline per acre lost was very high.

The EPA Office of Federal Activities (OFA) is developing a computerized information system to track the permitting process in all Regions. When it is implemented there will be a uniform, nationwide data base available. Data categories which will be useful in assessing cumulative impacts are being considered--location, type of activity, size, National Wetland Inventory classification (R. Koke, EPA, pers. comm.).

II.B.3.c. Research approach

The first step in assessing cumulative impacts is to summarize, within watersheds, ecoregions, and regions, the losses (area by wetland type) that have occurred in recent years. The percentage of each wetland type should then be calculated from recent inventories (the FWS's National Wetland Inventory maps), together with a rough indication of the functions most important to that wetland type. The resulting inventory would make it possible to evaluate permits in wetlands for which little habitat remains and/or where critical functions are predominantly carried out by that wetland type.

Acreage losses for past years (e.g., 1975-85) can be obtained from several sources--summaries of COE permits, State agency records, USGS hydrological unit maps, and evaluation of aerial photographs, including those with multispectral imagery. Problems with permit data are that not all wetland losses are covered by COE permits, and the ratio of permitted to non-permitted losses is not constant through time. Problems with aerial photography data are the extensive time requirements (as in the National Wetland Inventory of current acreages by wetland type) and difficulty of classifying wetland type from photos. It is not clear which approach to assessing cumulative acreage losses will prove most efficient. Thus, a "cost-benefit" evaluation of these two approaches is recommended prior to proceding with the compilation of permit data.

There are several recommendations for improving the data-logging system being developed by OFA. As presently planned, the Information System will only include data beginning in the year it is implemented; it will not include historical losses. Several of the Regions have computerized records of permits they have reviewed. The possibility of combining these individual systems with the OFA system should be explored and then implemented.

The WELUT-FWS has begun collecting wetland impact literature to assess prior impacts on wetlands by geographical area. Their Wetland Impacts Database will be designed to generate a list of articles on a specific impact type or all impacts for a given hydrologic unit, Hammonds's landsurface form, Bailey's ecoregion or state. The FWS database currently contains information on author, year, citation, location, landform, ecoregion, hydrounit, wetland type, and impact, and an abstract of the article. This effort is still in the early stages of development, and it is recommended that EPA follow its development as part of the feasibility study.

From the experience of Richardson in North Carolina, it is clear that the configuration (e.g., length of shoreline) and location of the acreage lost must also be included in the data base.

Mitigation by creation or restoration should increase wetland acreage, so the same kinds of data should be recorded for the gains as well as the losses.

Unfortunately, a data base which tracks only 404 permitted wetland losses will include less than half of the total (B. Wilen, FWS, pers. comm.). Wetlands are lost under the provisions of the nationwide and regional permitting systems, and through unregulated and illegal activities. Since the ultimate goal is to develop a means to assess and predict cumulative impacts, it would be important to include additional information wherever possible. Existing data sets, such as the survey of habitat changes along the Columbia River (Pacific Northwest) over the past century (Thomas 1983), could be used to expand the data set for a particular watershed. This information could be used to validate the effectiveness of using only the 404 permitting record to assess cumulative impacts.

It is recommended that the "cost-benefit" evaluation of the two approaches be completed for selected ecoregions, and that the preferred alternative be pursued, if sufficiently promising.

II.B.3.d. Time line and cost to create data base of wetland loss.

WORK/PRODUCTS	COST PER YEAR OF PROGRAM (K/year) 1	2	3	4	5	6	7	TOTALS	
Determine best strategy for documenting acreage loss (permits vs. aerial photo)		100						100	700
Develop historical data base of wetland loss for selected Regions			250	250	100			600	

II.B.4. Relate functional losses to area losses

II.B.4.a. Objective

To develop graphical models relating acreage losses to functional losses; and thus predict the cumulative impacts of wetland loss on the regional scale. Specifically, the assumption of linearity between area and function must be tested.

II.B.4.b. Background and rationale

It is assumed that many wetland functions are related to habitat area in a simple manner (cf. assumptions of linearity in Adamus 1983). Thus, as wetland habitat losses are evaluated on a piecemeal basis, the overall impact does not become obvious until threshold points are exceeded. One serious impact that occurs with excessive loss of habitat is the endangerment of wetland-dependent species. Another, less obvious effect is the reduction in genetic diversity of small populations, which ultimately imperils the species. It is an indication, rather than a measure of functional changes that occur with declining wetland area. Clarification of the relationships between area loss and function is thus necessary to prevent the irreversible degradation of natural wetland ecosystems, both at the regional scale, as well as within watersheds.

The few methods that are available provide only general guidelines or descriptive accounts of potential impacts; they rely heavily on qualitative and subjective judgements (Witmer In press). Quantitative relationships to assess the impact of cumulative habitat losses are lacking. It is not now possible to evaluate 404 permit requests on the basis of anticipated cumulative losses.

In addition to the need to specify maximum permissable losses, the ability to predict cumulative impacts will allow EPA to plan and manage alterations of wetlands within ecoregions much more wisely. EPA is becoming involved in an "advanced identification" process. Regions are identifying wetlands where permit requests are unlikely to be approved. This necessitates an approach that considers the ways in which ecosystems are linked. Both protective and preventative management schemes must consider these linkages.

Harris (1984) developed a procedure to manage old-growth forest in the Pacific Northwest based on the principles of island biogeography. His goal was to develop a management system that would allow for the continued harvest of timber while preventing the loss of genetic diversity of the biota. It combines conservation and development planning into an integrated landscape approach. He is presently testing the application of this approach in the bottomland hardwood system in the Suwannee River watershed in Florida. Similarly, Ambuel and Temple (1983) and Robbins (1979) have studied area-dependent changes in bird communities and vegetation. The approach appears fruitful, and further investigation is warranted.

The goal of assessing cumulative impacts complements EPA's ecoregion research. The concept of ecoregion is based on the premise that ecosystems and their components display regional patterns that are reflected in combinations of spatial characteristics (P. Larsen, EPA, pers. comm.), i.e., within region variance is less than between region variance (Hart 1982). Within an ecoregion particular types of wetlands will dominate because of the ecoregion's characteristics. The forcing functions determine what can exist in that area (Warren 1979).

The ecoregion research has focused on ecoregional characteristics of streams. A project to identify "reference streams" is being conducted in Region 8. The least degraded systems in the ecoregion are characterized and then comparisons are made with more severely altered systems to determine how impacts affect the system. Identifying "reference wetlands" and comparing them with more modified wetlands is consistent with this approach.

The capacity to assess and predict cumulative impacts is vital to the daily evaluation of permit requests. Moreover, it is integral to the management of wetland associated systems.

II.B.4.c. Research approach

While the most efficient techniques for assessing past acreages losses within Regions are being examined (Section II.B.3), existing information needs to be evaluated. The assumption of simple area-function relationships (e.g., linearity) can be tested for selected populations, species, and communities. The components that can be examined are declines (as habitat declines) and ability to rebound (as habitat expands locally, through mitigation).

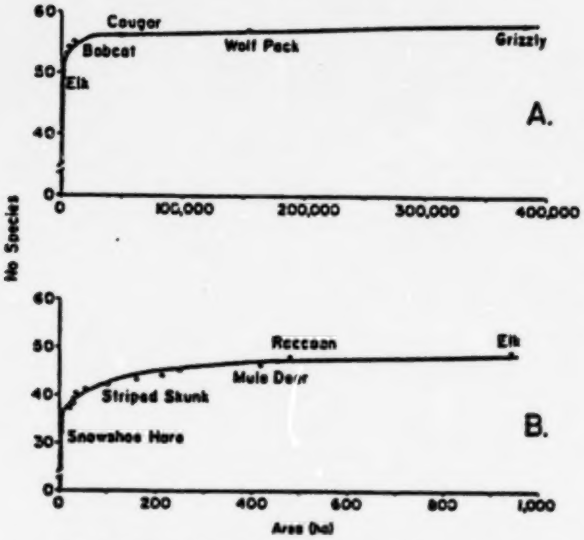
There are two major approaches that could be followed. First is the correlation approach, wherein existing long-term data sets (e.g., Audubon bird counts for wetland-dependent birds; nesting data for waterfowl; Nature Conservancy records) could be related to wetland habitat acreages where those data can be readily summarized (e.g., within watersheds or small ecoregions). Paired watersheds (with different degrees of wetland acreage losses) might provide the data for area reductions where historical data are lacking. Data of this type from terrestrial systems are graphed in Figure 7. Searches for long-term or broad-based inventories have not been undertaken in this planning effort. The lists of priority research sites being compiled at the NWTC workshops may identify such data sets for wetlands.

The second approach is experimental, wherein habitat area is altered (either through reduction or expansion), and the response of wetland-dependent species is assessed. Large-scale reduction experiments are not recommended, because of the obvious damages and precedent-setting impacts. However, small-scale experiments should be very effective if the species assessed are ones that respond to small losses in habitat. For animals, this would be species with small "home ranges" (e.g., insects, small mammals); for plants, species of small size and narrow habitat requirements (e.g., rare or uncommon annuals). It is quite likely that insects could provide some of the best species-based indicators of ecosystem functional change. Their habits are often highly specialized, and their role in energy flow is enormously important.

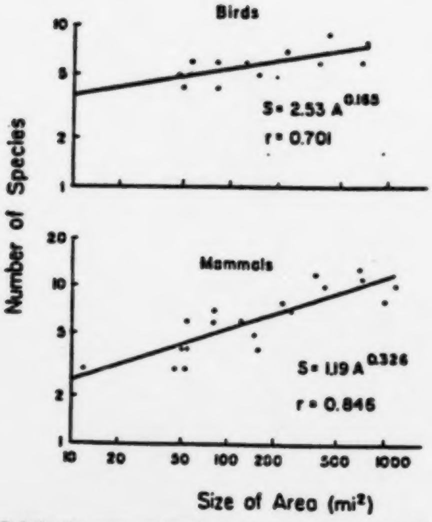
It is recommended that a brief feasibility study be funded that will lead to a decision to pursue the correlation and/or the experimental approach to generate the necessary landscape models for assessing impacts of cumulative habitat loss. The decision rests on the availability of existing data sets for correlating loss and function, and the availability of appropriate situations for experimental manipulation of habitat losses or gains to develop the necessary data sets. The Garrison Diversion project in North Dakota might provide the opportunity to decrease and to increase habitats systematically within the potential mitigation area of 14,000-acres, with the concurrent assessment of species and community responses. Appendix VIII describes this and other projects.

It is also recommended that innovative techniques for combining data sets be evaluated to obtain the most comprehensive indicators of ecosystem response. Sharazi and Hart (1984) have synthesized individual data sets for similar classes of information (e.g., species diversity, wetland function, ecoregion, wetland type). The pattern generated represents a collective knowledge, a "unified relationship," that summarizes a group of tests. They have applied the technique to dose-response relationships to predict chemical effects. The concept is analogous to assessing cumulative effects of wetland loss (Figure 8). The "dose" is the loss of wetlands (expressed as a percent of the original acreage in the region) and the "response" is the quantitative expression of a change in function.

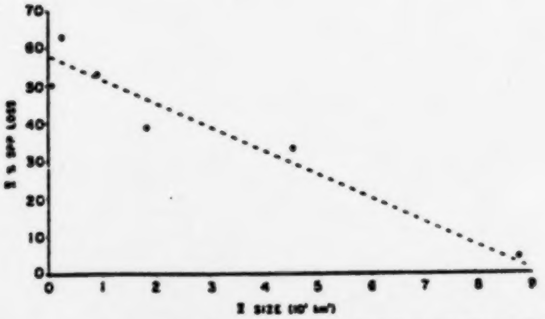
Figure 7. Examples of the types of information used by Harris (1984) to assess the cumulative impacts of the loss of old-growth Douglas fir forest.



Theoretical maximum species-area curve for western Oregon mammals based on the cumulative number of species whose home-range size is encompassed by any given area. B is simply a higher resolution extension of A. The area below the curve represents the feasible domain for empirical species-area curves.

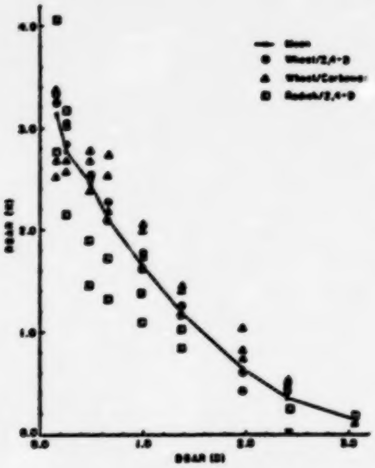


Relation between number of permanent resident boreal bird species, the number of small, boreal mammal species, and the size of isolated mountain ranges (>7,500 ft, 2,300 m elev.) in the Great Basin (modified from Brown 1978).

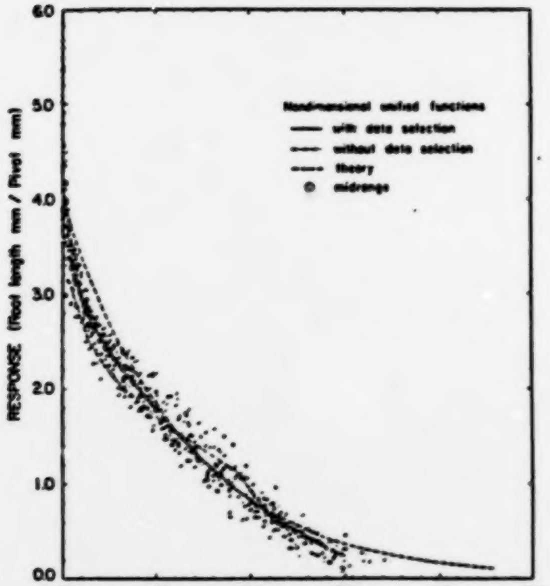


Average percentage loss of large mammal species as a function of island size for isolated ranges in the northern Rocky Mountains (data from Picton 1979).

Figure 8. An intermediate step and the final product in the data synthesis process developed by Sharazi and Hart (1984). Note that data from several experiments are combined to produce a unified response curve.



A graphic display of a scaling step showing the merging together of points from various tests and averaging along the response axis to form a unified curve.



A unified dose-response pattern emerging from scaling root elongation bioassay tests, and comparison of theory and unified functions with and without data selection.

Ultimately, a computer model should be produced that can serve 404 personnel in assessing cumulative impacts. Data from several large regions could be reviewed and acreage losses related to changes in densities of well-studied species (e.g., rare wetland plant censuses, data on wetland-dependent birds from Audubon Christmas counts, etc.). The relationship would indicate the danger points where further losses cannot be permitted.

The problem is somewhat site-specific, in the sense that the geography, e.g., the soils, hydrology and topography, of the basin will have a strong influence on the response curve. For example, if the wetlands exist in a catenated sequence, they may possess substantial excess load-bearing capacity that will ameliorate the impact of habitat losses. Therefore, these models would require exacting set-up procedures designed around actual mapped watersheds. In such models, the functions of each type of wetland would probably have to be described in rather simple terms, to avoid unmanageable complexity. These descriptions might be derived from a thorough review and synthesis of the behavior of detailed process-based ecosystem models.

Once the most feasible approach for identifying relationships between cumulative wetland loss and functional loss are identified, both the preparatory research and the modeling should be funded.

II.B.4.d. Time line and cost to relate functional loss to acreage loss.

WORK/PRODUCTS	1	2	3	4	5	6	7	TOTALS
Determine feasibility of developing models to relate functional loss to acreage loss		75						75
Field studies to document relationship between functional loss and acreage loss			25	500	500			1025
Model to relate functional loss to acreage loss						150		150
								1250

COST PER YEAR OF PROGRAM (K/year)

II.C. MITIGATION

Goal:

To improve methods of enhancing wetland habitat values; to improve methods of restoring highly disturbed wetlands; and to determine if projects proposed as mitigation for dredge/fill activities in wetlands are likely to mitigate losses; and to provide guidance for the design of effective mitigation projects.

II.C.1. Background and rationale

This initiative has been recommended both by 404 Regional personnel and by the scientific community. A number of procedures have been proposed to enhance existing wetlands or to create wetland habitat from highly disturbed wetland areas or from upland habitats. Vegetation has been planted in numerous mitigation projects, but the existence of typical wetland functions over the long-term (especially use by animals) remains undocumented for most artificial wetlands. Reasons for success or failure usually go undetermined.

In some Regions where development pressure is high, the areas available for mitigation are extremely limited, and questionable trade-offs are being permitted (e.g., the dumping of dredge spoil onto existing salt marsh habitat and calling it a "bird nesting island," a practice that is becoming common in Southern California---this is a loss, not a gain, in functional value). In other places, where there are many opportunities for restoration of altered systems (e.g., bottomland hardwood areas that were drained for farming, but have been abandoned; prairie potholes that have been drained and plowed), it is unclear how to assess the potential of disturbed wetlands for restoration (c.f. the 14,000-acre Garrison Diversion Project in North Dakota, and others summarized in Appendix VIII).

There are three major needs for EPA: assessing the kinds of activities proposed for mitigation; establishing the best management practices for restoring altered wetlands; and determining whether or not they successfully mitigate permitted losses. Regional offices must be aware of the range of mitigation practices used in their Region, be able to decide whether or not proposed mitigation projects will cause a net loss of in-kind wetland function, and determine whether or not the implemented project has fulfilled its stated purpose. Overall, the desire to know more about mitigation planning and implementation was rated high by EPA Regional Offices, and it was identified as an issue by the Narragansett Laboratory's survey of estuarine wetland information needs (Charles A. Menzie and Assoc. 1985).

II.C.2. State of knowledge

There are several types of mitigation: a) impact avoidance (i.e., through denial of proposed project or alternative site selection); b) impact minimization (i.e., through on-site modification techniques); c) on-site compensation techniques; and d) off-site compensation techniques. Deliberate modifications can be required. Very often, the success of such modifications goes undocumented; occasionally, there is a brief period wherein contractors must demonstrate that project specifications have been carried out.

The most thoroughly documented habitat restoration projects are the dredged material islands that have been created and studied by COE. These coastal wetlands have proven suitable for vegetation establishment and bird usage. Coastal dunes have also been manipulated to restabilize eroding sand, but not always with the intended result. Planting of non-native beach grasses produced excessively high dunes in some regions that were later undercut. While short-term stabilization was obtained, long-term stability was not. An artificial habitat must be as resilient and as able to achieve stability as natural habitats.

The ecological literature on assessing the success of mitigation projects is sparse. While there are several books on techniques for establishing vegetation, there are few detailed documentations of long-term changes in the total wetland ecosystem that followed vegetation planting. Several ideas on how to assess mitigation success were obtained from P. Zedler (SDSU, pers. comm.), who has created artificial vernal pools with funding from EPA.

The task in determining whether or not an artifically created or modified habitat can replace habitat lost to development involves two elements: 1) comparison of biotic and abiotic components of the created/modified habitat, and 2) prediction of future change in the created/modified habitat--i.e., will it become more or less like the natural habitat? Both are difficult because of high spatial and temporal variability. No two natural habitats are identical; the same habitat is not identical from year to year or season to season.

The Comparison Problem. In order to compare natural with artificial habitats, there must be replication in the created/modified habitat to characterize means and variability in features present. Single variables (e.g., vegetation cover) will be inadequate for comparing artificial and natural habitats. The ecosystem is too complex, and the interrelationships of variables (e.g., change in dominant species as vegetation cover expands) are important. Multivariate statistics will be required to compare artificial and natural habitats, and a number of attributes will need to be assessed to characterize both types of habitats. Discriminant analysis may prove very useful.

For natural and artificial habitats, a number of system attributes (e.g., cover, plant height, number of species, hydroperiod, etc.) could be used to determine the similarity of the modified ecosystem to natural systems. Ordination or classification (dendrogram) techniques could also be utilized to compare large numbers of habitats. In all cases, the mitigation program will be judged a complete success when artificial habitats cannot be distinguished from a set of natural habitats.

The Extrapolation Problem. Predicting how a community will change through time requires consideration of intrinsic biotic features (e.g., competition, predation) that control community development as well as extrinsic features, which may be abiotic (e.g., catastrophic events) or biotic (e.g., predator exclusion) that also modify species composition or function. Because extrinsic features would modify both natural and artificial wetlands, the focus of research on temporal trends should be on the intrinsic features of each community.

II.C.3. Past mitigation projects

II.C.3.a. Objective

To catalog and evaluate past mitigation projects for problems, likelihood of failure, and reasons for success/failure.

II.C.3.b. Rationale

Review of projects in areas with a long history of mitigation can identify common problems and suggest means of preventing failures. Few individuals have attempted to evaluate mitigation projects over a wide area, but even a cursory review of attempts to enhance, restore, or create wetlands can lead to recommendations for improved mitigation. Failure to plan correctly for the altered wetland's hydrology appears to be the most basic and consistent problem with mitigation projects. There is no need to repeat such errors, when the consequences are easily documented. Because each Region has many types of wetlands with different hydrology, regional reviews of mitigation projects are recommended.

An important component of this effort will be information exchange among Regional personnel. Several opportunities to learn from the broader management community are expected to develop in the near future. At least two workshops on mitigation are being planned for 1986, one in the state of Washington, and one by the Association of State Wetland Managers. EPA 404 Regional personnel should attend these workshops and receive the proceedings.

II.C.3.c. Research approach

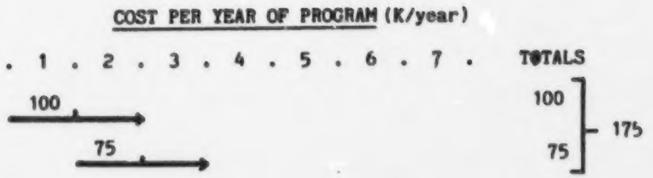
The types of mitigation projects that are most often proposed within Regions need to be quantified (e.g., no project allowed, use of alternate sites, marsh creation, tree planting, increased tidal circulation, creating wetland habitat from upland, changing one type of wetland to another). Next, it is necessary to determine the implementation success of each type of mitigation project, identifying the causes of success or failure wherever possible. This should lead to a list of "red flags" for each Region, alerting 404 personnel to mitigation projects that have not fulfilled their promise (e.g., improperly contoured topography resulting in too much or too little inundation for the desired wetland ecosystem).

II.C.3.d. Time line and cost to evaluate past mitigation projects.

WORK/PRODUCTS

Survey past mitigation projects to determine if they met stated goals

Provisional handbook of mitigation techniques for different wetland types



II.C.4. Experimental component

II.C.4.a. Objective

To develop an experimental approach to mitigation so that cause-effect relationships can be identified and successful techniques for wetland restoration/creation can be developed; and to provide design guidelands for effective mitigation techniques.

II.C.4.b. Rationale

First, EPA needs to know how hydrological conditions determine the functional value of a wetland. Under normal circumstances, this cannot be learned from short-term studies of natural wetlands, because few extremes will be experienced. Chances are that a one- or two-year study will coincide with average hydrological conditions, and not reveal cause-effect relationships. With longer data sets, a broader range of conditions is documented, and shifts in biota can be associated with shifts in hydrology. To determine these relationships in the quickest way, with good controls on the hydrological features, requires a large-scale experimental program.

By manipulating hydroperiod (frequency, duration and timing of inundation or soil saturation) and hydrological energy (current speed or flow-through rates) in large-scale mitigation projects, it will become possible to determine the effects of these variables on wetland community structure and functioning. Some examples of altered hydrology exist which can be used to assess effects (e.g., impounded bottomland forests in North Carolina; Kuenzler, UNC, pers. comm.). Others will need to be created using future mitigation projects.

Second, EPA needs to determine how best to control hydrology and other "forcing functions" to achieve the highest-value artificial or restored wetlands. This goal goes hand-in-hand with the first goal--with an understanding of cause-effect relationships comes the ability to manipulate the ecosystem to achieve desired results. As landscapes shift further and further away from their natural condition, the process of management becomes more active (rather than passive, preservation-oriented), and the need to understand causal mechanisms becomes urgent. One of the biggest questions that has haunted efforts to construct wetlands in Florida is the hydroperiod and depth of inundation requirements of newly created wetlands versus mature systems (Mark Brown, UF, pers. comm.). Moreover, there is the problem of how to collect and handle the volumes of seeds and/or plant material required for projects hundreds of acres in size.

II.C.4.c. Research approach

There are many opportunities to incorporate large-scale experiments into the design of mitigation projects. For large mitigation projects, where several acres of habitat are scheduled for improvement, it is possible to develop manipulative experiments to determine a) how altered wetlands function and b) how to enhance desired functions.

Previously drained prairie potholes and bottomland hardwoods may provide opportunities to determine how best to restore altered wetlands. The questions that arise are what size wetland is necessary to be functional; what plant community is most effective in supporting the food chain; what hydrological condition produces that vegetation and food web; and what configuration and arrangement of individual wetlands is most effective in attracting wetland-dependent wildlife. With projects of several thousand acres of wetland, such as the Garrison Diversion Project or the Rainwater Basin in Nebraska, subsets of the landscape could be identified for controlled experiments (see Appendix VIII).

With much smaller projects, much simpler questions can still be answered, such as what planting scheme will produce the desired vegetation most quickly. Treatments would vary selected factors, such as species planted and planting density within different elevations (hydroperiods), different proximities to flowing water (hydrologic energy), and different substrate types. Also, it would be valuable to know under what circumstances plants would "volunteer" to recolonize an area.

Every mitigation project should be evaluated for its research potential, especially the opportunity to identify causes of success or failure. For those that provide such opportunities EPA should solicit an associated research project. A portion of the EPA research budget should be reserved to fund research where the mitigation project lends itself to good experimentation and appropriate research projects are proposed. The main needs are careful design of the experimental aspect of each project followed by key observations at appropriate intervals.

Multi-year investigations are needed. COE, FWS, and EPA should collaborate to recommend experimental treatments to be included in each project design. Before the mitigation plan is approved, it should specify exactly how habitats will be altered to meet experimental objectives. The opportunity for such experimentation would generate a request for proposals to follow the treatments in detail for at least two years and again at the fifth year after implementation.

The results of these investigations need to be integrated in a form suitable for use by Regional staff in evaluating the effectiveness of proposed mitigation projects.

II.C.4.d. Time line and cost to refine and develop mitigation techniques.

WORK/PRODUCTS	1	2	3	4	5	6	7	**TOTALS**	
Experimental work in cooperation with existing mitigation projects		50	300	300	300			950	1025
Final handbook of mitigation techniques						75		75	

COST PER YEAR OF PROGRAM (K/year)

III. ASSOCIATED RESEARCH PROGRAMS AND RECOMMENDATIONS FOR OTHER AGENCIES

III.A. CHARACTERIZATION OF TARGET WETLANDS

Goal:

To substantiate the values of target wetlands, those where the anticipated level of regulated activity most seriously threatens wetland functions protected by the Clean Water Act and those for which information is not readily available.

III.A.1. Background

Each of the Regional offices is developing lists of wetlands that might be appropriate for priority wetland status. Regions have proposed different numbers of wetlands (from one to many) for priority status, and they have used different criteria for inclusion of wetlands. The process of protecting wetlands under 404(c) is lengthy and labor intensive (Meagher, pers. comm.).

Each Regional office (cf. Appendix I) also indicated that there are unique types of wetlands and unique problems associated with their Region. Tundra wetlands, pocosins, montane wetlands, bogs and fens, prairie potholes, vernal pools and desert seeps are examples of systems for which the hydrology and biota differ enormously from the most studied ecosystems (i.e., coastal saline marshes). Thus, there are individual problems for which extrapolations from existing data are inappropriate.

The research effort should assist in characterizing functional values of wetlands that require the most detailed evaluation of permit applications. Those wetland types will differ with Region and will be determined by a) the pressures for development, b) the size of the wetland, and c) the degree to which wetland functions are presently unknown or unsynthesized.

III.A.2. Recommendation

The ongoing ecosystem synthesis program of FWS, which produces "community profiles" of selected wetland types, should be expanded to include wetland types targeted for special emphasis by EPA regions. These profiles synthesize existing information for a wetland type within a large geographical unit. Ecological attributes are summarized and management problems/recommendations indicated. In addition, a complementary approach is recommended where the new literature on all wetlands types (all functions) is summarized every two to four years.

Prairie potholes are one wetland type with high information demand for improved management. To date, no summaries of technical information on prairie potholes have been developed. However, EPA provided partial support for a National Wetland Technical Council workshop on prairie potholes held in early November 1985. Eleven review papers will be presented, each of which will summarize one aspect of prairie pothole wetland functioning. If the proceedings are not published in their entirety, this information base may be suitable for summary as a community profile.

III.A.3. Time line and cost to produce community profiles.

WORK/PRODUCTS	COST PER YEAR OF PROGRAM (K/year)								
	1	2	3	4	5	6	7	TOTALS	
Produce community profiles for priority wetlands (3 per year)	30	30	30	30	30			150	150

III.B. LONG-TERM STUDIES OF BOTTOMLAND HARDWOODS

EPA has worked closely with COE and FWS in identifying bottomland hardwood forests as a high priority wetland type. Rates of habitat loss are high, and impacts of multiple alterations are accumulating. In Mississippi, EPA and FWS are collaborating on a project in the Yazoo watershed to examine the sediment-trapping ability of wetlands, with watershed-level models being developed to assess the effects of wetland losses on the landscape.

COE is proposing to focus its 1986-87 research budget on a selected site within the Mississippi basin. Site selection is in progress, and detailed ecosystem-level projects are being planned. All three major wetland functions (water quality, hydrology, and food chain support) will be examined within a large site. USGS may assist with some of the hydrological studies. The wetland-intensive approach is highly complementary to the function-intensive program of water quality research recommended. EPA should perform some of the manipulative experiments within the COE site, as indicated in Section II.

In addition, the proposed studies of DOE in bottomland hardwood forests at Savannah River, Georgia, are valuable to the overall characterization of priority wetland types. EPA may wish to fund some manipulative work at the Savannah River bottomland hardwoods site.

The bottomland hardwood focus is widely recognized by Federal Agencies as having high priority for research. It will be increasingly important for EPA to keep abreast of efforts and findings. The Interagency Wetlands Coordinating Committee provides the structure for such interactions.

III.C. QUANTIFYING HYDROLOGICAL AND FOOD CHAIN SUPPORT FUNCTIONS

USGS and COE are viewed as having responsibility for undertaking detailed studies of wetland hydrology, and FWS is seen as having responsibility for quantifying food chain support functions. These are important areas for research, but it is not recommended that EPA spread its resources over all functions in all wetland types.

It is recommended that FWS continue to develop data bases support for wetland community profiles. It may be desirable for EPA to assist with funding for selected wetland types, especially where EPA-funded research provides or has provided a major contribution.

The Association of State Wetland Managers has tentatively scheduled a workshop on wetland hydrologic functions for late 1985/early 1986. The workshop will provide an opportunity for personnel from all the regulatory agencies to update their understanding of wetland hydrology.

III.D. WETLAND DELINEATION RESEARCH

Goal:

To identify in the field the geographical boundaries of wetlands falling under the jurisdiction of Section 404 of the Clean Water Act.

III.D.1. Background

The COE has been developing a multiparameter approach for identifying and delineating wetlands under the 404 program. EPA has been developing a similar methodology (Sipple, EPA, pers. comm.). It is recommended that the COE and EPA continue this effort jointly to establish a mutually acceptable methodology. The FWS and SCS have developed a list of wetland plants and a list of hydric soils, respectively, which will be very useful input to any joint COE-EPA methodology. The FWS is also developing a study plan to address how their wetland plant list can be used to define wetlands under their classification system (Cowardin et al. 1979).

III.D.2. Objective

Acquire the ability to respond to information needs as controversies develop over wetland boundary determinations.

III.D.2.a. Recommendation

Scientific consensusing can be effective in determining what habitats function as wetlands. Regional offices should call upon scientists who receive EPA funding (e.g., through individual grants and Centers of Excellence) to provide expertise in identifying wetlands. In coastal areas, scientists who work with Sea Grant Funding are expected to disseminate research findings to agencies; they are an additional source of expertise.

III.D.2.b. Future approaches

Field Survey: Coordinated study of soils, vegetation, fauna, and hydrology along transitions from wetland to upland should be encouraged in wetlands where controversies develop. Ephemeral wetlands are most likely to be contested because hydrological evidence of wetland status is not always present. The boundaries of riparian areas, particularly western riparian areas, are also difficult to discern, because functional values often extend beyond the area of hydric soils.

Experimental Research: Testing of selected hydrophytes for obligate wetland status will be needed if the FWS plant species list, or EPA's draft jurisdictional methodology, which relies to large extent on obligate hydrophytes, are contested. Obligate status of plants (a "red flag" feature) can identify wetland boundaries in regions where hydrological data are difficult to obtain (e.g., seasonal wetlands) and where hydric soils have not developed (e.g., recent alluvial fans).

III.E. WETLAND VALUE ASSESSMENT METHODOLOGY

Goal:

To insure that EPA can evaluate individual wetland decisions within a framework of national priorities.

III.E.1. Recommendation

No new funding is suggested for the purpose of developing new assessment methodology. Assessment strategies have already been reviewed repeatedly (e.g., Whigham and Brinson 1985), and COE has undertaken an effort to refine, computerize and test the FHWA Technique, which is deemed most suitable for wetland value assessment. Although scientists remain critical of the method, it is the most thorough system available, and it requires evaluation of all three major wetland functions (water quality, hydrology, and food chain support). Some States have already tailored the FHWA Technique for their own wetland types; others are in the process of modifying it. The research proposed in Section II., especially Section II.A., will contribute to the refinement of the FHWA Technique. However, maximum benefit will be derived only if refinement of the technique proceeds in parallel with the research, not in a "leap-frogging" manner, i.e., conduct research, incorporate data into method, do more research, etc. The assessment method should be considered in the planning of the research and during its evolution, not only at its conclusion.

EPA is providing some support of regional workshops being carried out by the National Wetlands Technical Council. Each of the seven workshops has as its goal the evaluation of scientific literature utilized in the FHWA Technique. Assuming that the method is only as good as the information available for its use, the scientific evaluation of the literature base will identify major data gaps and indicate where the FHWA Technique is inadequate due to lack of information.

IV. TECHNICAL INFORMATION TRANSFER

IV.A. GOAL

To provide visible, authoritative, and scientifically credible information on major wetlands issues of concern to EPA.

IV.B. APPROACH

Use existing expertise to:

1) Expand COE training sessions to include additional staff from EPA and other agencies.

2) List and describe the existing data bases on wetlands and how to use them.

3) Develop workshops where agency staff members and scientists exchange information and experiences.

4) Pass funding to FWS to develop and distribute "Community Profiles" of target wetlands.

5) Appoint a representative to sit on the Interagency Wetland Coordinating Committee and keep abreast of developments in all EPA wetlands research programs. This person would also chair the technical advisory panel for water quality experimentation and guide the development of reports and broad-scale information syntheses.

V. SUMMARY OF RECOMMENDATIONS

The research plan focuses on three major information needs:

* Quantifying the water quality functions of freshwater wetlands,

* Assessing the cumulative impacts of incremental habitat losses, and

* Determining how mitigation projects can lessen the impact of habitat loss.

The following tables summarize the time lines and cost for the work/products presented in the text of the research plan.

Other areas of important research have been and should continue to be the focus of other agencies. Field studies of selected wetlands (e.g., long-term analyses of bottomland hardwoods), food chain support functions, hydrological functions (i.e., flood storage and modification of ground water recharge and discharge), are important areas for research; and it is essential for all agencies to agree on wetland delineations and value assessment methods. It is not recommended that the EPA research program emphasize these areas of study.

Implementation of this research plan will require extensive coordination between Regions, as well as between EPA and other Federal agencies, State agencies and the university community. The research will need to be coordinated by someone or some office who has a good working relationship with these groups. Furthermore, since many of the proposed activities will involve long-term projects and manipulative experiments, this coordinating function will need to have continuity.

WORK/PRODUCTS	COST PER YEAR OF PROGRAM (K/year) 1	2	3	4	5	6	7	TOTALS	
WATER QUALITY									
Assess the aggregated role of wetlands in altering the quality of water in receiving water for selected ecoregions.									
Report on feasibility of combining watershed data across entire ecoregions		75						75	475
Report on assessment of importance of wetlands to receiving water quality for 2-4 ecoregions				100	250	50		400	
Produce techniques for evaluating the role of individual wetlands in altering receiving water quality on a watershed basis.									
Plan and construct artificial and *in situ* mesocosms for experimental work (★ indicates that these mesocosms are required for the work/product)									
COE bottomland hardwood site	75							75	550
Two additional *in situ* and two artificial mesocosms	25	450						475	
NUTRIENTS									
Provisional wetland rate model for uptake, transformation and release of N&P by different types of wetlands (based on literature)	50	125						175	1725
Provisional watershed model of effect of wetlands on N&P in receiving water (based on literature)	50	150						200	
★ Validate models and collect additional data as necessary									
COE bottomland hardwood site		100	100					200	
Two additional *in situ* and two artificial mesocosms			50	400	400			850	
★ Final wetland rate model for uptake, transformation and release of N&P by different wetland types (based on new data)					150			150	
★ Final watershed model of effect of wetlands and N&P in receiving water (based on new data)					150			150	
★ Define simple decision criteria for evaluating water quality functions of individual wetlands						75		75	75

WORK/PRODUCTS

WATER QUALITY (continued)

ORGANIC CHEMICALS

COST PER YEAR OF PROGRAM (K/year)

	WORK/PRODUCTS	1	2	3	4	5	6	7	TOTALS	
	Conceptual wetland rate model for guiding research experiments		50						50	2650
★	Collect data on uptake, transformation and release of organic chemicals by different wetland types									
	COE bottomland hardwood site		200	200					400	
	Two additional *in situ* and two artificial mesocosms		150	50	500	300			1000	
★	Final wetland rate model on uptake, transformation and release of organic chemicals by wetland types				200	200	100		500	
	Watershed models for organic chemicals by modifying nutrient watershed models as necessary				75	75			150	
★	Validate models					250	300		550	
★	Define simple decision criteria for evaluating water quality functions of individual wetlands.						75		75	75
	Determine residue analysis for selected organic chemicals			150					150	1050
★	Evaluation of interactions between organic chemicals and nutrients for use in water quality models					175	175		350	
★	Impact assessment for effects of organic chemicals on wetland vegetation				200	200	150		550	

WORK/PRODUCTS

WATER QUALITY (continued)

METALS (All $ assume funding organic chemicals)

COST PER YEAR OF PROGRAM (K/year)

	Work/Products	1	2	3	4	5	6	7	TOTALS	
	Conceptual wetland rate model for guiding research experiments		50						50	1300
★	Collect data on uptake, transformation and release of metals by different wetland types									
	COE bottomland hardwood site		75	100					175	
	Two additional *in situ* and two artificial mesocosms			50	200	200			450	
★	Final wetland rate model on uptake, transformation and release of metals by wetland types				100	100	50		250	
	Watershed models for metals by modifying nutrient watershed models as necessary					50	25		75	
★	Validate models					150	150		300	
★	Define simple decision criteria for evaluating water quality functions of individual wetlands						75		75	75
	Determine residue analysis for selected metals				75				75	975
★	Evaluation of interactions between heavy metals, and nutrients and organic chemicals for use in water quality models.				200	200	50		450	
★	Impact assessment for effects of heavy metals on wetland vegetation				150	150	150		450	

WORK/PRODUCTS	COST PER YEAR OF PROGRAM (K/year) 1	2	3	4	5	6	7	TOTAL	
CUMULATIVE IMPACTS									
Determine best strategy for documenting acreage loss (permits vs. aerial photos)		100						100	1950
Determine feasibility of developing models to relate functional loss to acreage loss		75						75	
Develop historical data base of wetland loss for selected Regions			250	250	100			600	
Field studies to document relationship between functional loss and acreage loss; to identify spatial patterns and minimum acreages to support selected wetland functions.			25	500	500			1025	
Model to assess cumulative functional loss.						150		150	
MITIGATION									
Survey past mitigation projects to determine if they met stated goals	100							100	1200
Provisional handbook of mitigation techniques for different wetland types		75						75	
Experimental work in cooperation with mitigation projects		50	300	300	300			950	
Final handbook of mitigation techniques						75		75	
ECOSYSTEM SYNTHESES									
Produce community profiles for priority wetlands (3 per year)	30	30	30	30	30			150	150

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APPENDIX I. SUMMARIES OF INTERVIEWS WITH EPA'S REGIONAL OFFICES

As part of the information gathering phase of this research plan 404 personnel at each of EPA's Regional Offices were interviewed. Four types of information were obtained and are summarized here:

1) A description of the permit review process,

2) Recommendations for research that would augment the permit review process,

3) Major concerns relative to the Region, and

4) Research in the Region.

A. EVALUATION OF 404 PERMIT REQUESTS

EPA becomes involved in the permitting process when a public notice is distributed by a local COE district. EPA personnel work closely with personnel from COE, FWS, National Marine Fisheries Service, and State and local agencies. Because of the size of the Regions and limited travel funds, the EPA personnel do not make site visits for most permit requests. They typically obtain site information from the FWS and/or State agencies, which very often have offices near the site in question. In some of the Regions, the agencies involved in permit review will meet monthly. One will be responsible for visiting the site and preparing a presentation for the meeting, including slides.

For larger or more controversial projects there will often be an interagency meeting at the site. This meeting will include FWS, COE, the State, the applicant and EPA.

A typical response to a public notice would describe the project and where information about the project and/or site was obtained. The evaluation of the permit would be structured around the 404b(1) Guidelines. Section 230.10 is critical to this evaluation; COE is required to deny permits that do not comply with 230.10. There are four broad conditions to consider:

1) Is there an alternative? This includes consideration of whether or not the project is water dependent.

2) Does the proposed project violate any water quality standards?

3) Does the project contribute to the degradation of the waters of the United States? This includes adverse effects on aquatic life and wetland dependent wildlife, on the diversity of life, and on the productivity and stability of the system.

4) Have the potential impacts been minimized?

Then it will be recommended that the permit be approved, denied or approved on the condition that modifications, as outlined in the evaluation, be made.

B. RECOMMENDATIONS FOR RESEARCH

The Regional personnel often had similar recommendations for research in the areas which became the major components of this plan. Their recommendations are summarized below.

B.1. Water Quality

It is difficult to document the potential water quality effects of a project.

What is the role of wetlands in the status of water quality? How does this change with season? How would the receiving body be affected if the wetlands were removed?

Wetlands are targeted as clean up areas for a watershed. How well do they function in this role? What features are critical to this function?

What is the role of wetlands in controlling the concentrations of agricultural pollutants and sediment loads in streams?, in mediating nonpoint sources of pollution?

How might small, isolated wetlands act to improve water quality? In particular, bogs, fens and prairie potholes were mentioned.

What is the role of the small, urban wetland in flood control and water quality?

B.2. Cumulative Impacts

How can cumulative impacts be assessed?, predicted? How broad of a point of view must be taken?

How does the piecemeal loss associated with small projects affect an area? Suspect that the cumulative impact of the incremental, small losses of wetlands result in a significant resource loss.

What is the relationship between wetlands in a watershed? How do upstream wetlands influence the functioning of coastal wetlands, fisheries? What is the effect of eliminating the export of material from upstream? One can miss the real importance of a wetland if it is viewed in isolation. The impact of a loss is most important in relation to the loss of function within the "system", i.e., watershed, ecoregion, ecosystem.

There is a need for a data base which will track acreage of wetlands lost and still remaining by wetland type and functional value.

B.3. Mitigation

Projects to repair or replace wetlands are difficult to plan, monitor and evaluate. Moreover, it is becoming more difficult to suggest that alternative sites be considered for projects. People want to use the land they have. An increasing number of permit requests are being received that propose mitigation "up front". Furthermore, they suggest that the mitigation will create a situation that is better than what exists.

Information is needed on how to advise the planning of mitigation projects. This includes:

* What are the elements of a good plan?
* What has worked and not worked? What has been the relative success with different wetland types, techniques? How far away from the site of the permitted activity can mitigation be allowed and realistically mitigate for the loss?
* What is a reasonable time line for follow-up? When is a project termed successful?

Other concerns relative to mitigation are:

- How can degraded areas be improved? Knowledge about the success of restoring and creating wetlands can be applied to the estimation of the "potential" value of degraded wetlands.
- How can mitigation fit in to management decisions? Is mitigation a viable way to manage wetland loss?
- How do the functions of restored and created wetlands compare with natural systems?

C. MAJOR CONCERNS RELATIVE TO THE REGION

REGION 1

It is difficult to track down the adverse impacts of a project, especially in regards to flood control (reduction in peak flood, frequency and severity of flooding), modification of ground water recharge and discharge, biological values, and aesthetics.

Forested wetlands, which are common in the Region, are considered lower in value than other types. This point of view may not be justified. For example, the controversy over the permit to build a shopping mail in Sweeden's swamp is of this type. Moreover, the claim is made that forested wetlands have little influence on water quality because the water mostly remains in the channel.

Need information on the effects of peat mining in Maine. What sorts of conditions should be attached to permit requests? How does this activity affect water quality?, flood control? How can these areas be restored? What are the values of a natural peat area?

Need a synthesis of information on channelization, highway construction, and impoundments for both large and small projects.

Region 2

There is a growing pressure for developing the freshwater wetlands in northwest New Jersey for shopping malls and housing. Need simple wetland delineation techniques, and ways to assess functional values.

Ability to assess the cumulative effects of the piecemeal loss of wetlands is critical. New Jersey is a particular problem.

The mangrove swamps of Puerto Rico need investigation. They are under increasing pressure for development.

Region 3

In areas with great development pressure there is a potential for water quality problems due to the increased use of septic tanks. Research on the use of wetlands in wastewater treatment would be useful, both in relation to the water quality problem and as a mechanism to preserve wetlands.

The construction of impoundments is a current issue. The loss of wetlands is important in itself, however, there is an additional concern about how these dams affect the watershed as a whole, and, in particular, how they influence the productivity of the coastal systems downstream. In the evaluation of such a permit it is customary to check the proportion of the wetlands within the watershed that have already been affected by impoundments. Need to document how eliminating the material exported from upstream wetlands impacts systems downstream.

Often agricultural drainage channels empty into wetlands. It would be important to know how the receiving body would be affected if the wetlands were removed, and how this changed with the season.

There are a number of small, isolated bogs and wetlands in the Region. It has been proposed that peat bogs in Pennsylvania and West Virginia be used to receive acid mine drainage. In Pennsylvania these small wetlands are used to polish the salt brine generated from blowouts of old, oil wells. It would be important to know how these wetlands might act to purify water, and how they might affect groundwater recharge.

Region 4

There are efforts to reimpound old rice fields in North Carolina, South Carolina and Florida for use in aquaculture and duck hunting. About 40% of South Carolina's coastal wetlands are behind impoundment dikes. This takes a sizeable amount of land out of the base that supports the coastal fisheries.

Pocosins, which occur in coastal North Carolina, are under great pressure from agriculture and peat mining interests. These wetlands may be important to the quality of the local aquifers. As the pocosins have been drained and converted to farmland, farm associated pollutants have been getting into the aquifers and surface waters.

What are the impacts of agricultural pollutants? How are these related to the loss of wetlands?

What are the impacts associated with the release of drilling muds in tidal areas? How would this activity affect the area's fisheries? How might it influence the hydrology? Presently, in the Mobile Bay, Mississippi Sound area no such discharge can be made within three miles of the shore. Due to the discovery of natural gas, there is growing pressure to change the policy so that drilling could proceed up into the Delta.

Region 5

It is very difficult to document potential water quality effects. Projects along the shore of Lake Michigan, for instance, are often so small in relation to the size of the system that it is meaningless to attempt to describe possible water quality effects from a single project. Cumulative losses exist, but can only be roughly predicted. Moreover, further loss of littoral habitat should be minimized.

The Region is interested in the prairie potholes and Savage Fen in Minnesota. They are examining the possibility of applying 404c restrictions to Savage Fen. It is a large calcareous fen that covers an area of approximately 40 acres. JRB Associates is doing a groundwater study of the area for EPA with the goal of documenting how changes in the hydrology might affect the biota and the quality of water in local wells.

Other concerns are the loss of littoral habitat and the effects of channelization.

Region 6

The most common types of impacts to this Region's wetlands occur as a result of the clearing of land for agricultural conversion, oil and gas exploration and production, building of marinas, and residential and commercial development.

Currently, the loss of marshland along the Louisiana coast is getting much attention. A number of factors contribute to this loss--the decreased input of sediment from the Mississippi River due to the construction of levies, subsidence, activities associated with the energy industry, digging of canals, the rise in sea level. The Region, along with other agencies, is interested in finding ways to slow these losses. The EPA Office of Policy Analysis and the Louisiana Geological Survey sponsored and led a workshop to discuss the problem. Representatives from federal, state and local agencies were invited. A research plan is being developed which will be used as a guide to solicit bids for research.

Bottomland hardwoods are another major focus of concern, in particular, the mitigation of losses.

In general, the isolated and degraded wetlands are the hardest to protect. It is argued that since a wetland is isolated or degraded it is of low value. Therefore, it would be important to know what function(s) these wetlands are performing and had the potential to perform.

Region 7

The herbaceous wetlands of the Rainwater Basin and the Sandhill Wetlands of Nebraska have been impacted through conversion to agriculture. These areas are used heavily by migrating birds. In addition, they may have a significant water quality function. Would like to have information on their connection with the area's groundwater and how their water quality function might influence the pollution problems associated with agricultural runoff.

Need information on how to restore wetlands that have been filled or drained.

The forested and riparian wetland in Missouri are impacted by channelization projects. The practice is to straighten streams by cutting through the meanders. Would like to know how this affects the hydrology, especially flooding, and water quality of the entire system.

Region 8

Prairie potholes (primarily in the Dakotas) are currently at the focus of many controversial issues. Not much quantitative information is available. However, of the four wetland types listed here the prairie potholes are recieving the most attention. USGS studies of their hydrology have documented their importance in flood control. However, we still need to know how their functions change seasonally, particularly with respect to hydrology and water quality, and how they relate to the functioning of the watershed.

The riparian systems of the Colorado River and its tributaries, and the Platte and the Arkansas Rivers are of interest. Need to know the functional values of such systems, particularly how they might protect in-stream water quality. It is felt that they are an important buffer, but they don't receive much attention. In arid areas, like much of this Region, they may serve a unique function.

Montane wetlands (at >9000 feet in elevation) are being greatly impacted by development of ski areas, summer homes and highways. Feel they may be critical to flood control, in protecting water quality and as habitat. There is no hydrologic data available for such systems, but EPA is faced with evaluating projects that will divert water from these areas. Many of these systems are important water supplies for urban areas. Although the pH of precipitation in the area is lower than expected, the lakes typically have a low buffering capacity. Therefore, the acid deposition may be critical even at low levels because of the local water chemistry. Those lakes with vegetated areas seem to have a better buffering capacity. This suggests a role for wetlands in the buffering of acid deposition.

Urban wetlands around Denver and Salt Lake City are subject to great pressure from development projects. These are typically small wetlands, often riparian. Very little is known about their role in general, therefore, it is difficult to predict the impact of eliminating them. Their value may be unique because of their proximity to the isolated, population centers of the Region.

Region 9

Although the planning of effective mitigation projects is of general concern, there has been such a great loss of wetlands in the Region that there are literally no places left to mitigate for proposed losses.

What is the relation of the coastal wetlands to the fisheries of this Region? This issue has been explored by research done on the East coast, but the results obtained in studies outside the Region do not often apply to the situation on the West coast.

Introduced species are a problem in this area. Dr. Michael Josselyn had proposed to study the impact of an introduced species of *Spartina* in San Francisco Bay. The proposal was not funded by EPA. However, the problem of introduced species remains. In some areas they have replaced native vegetation. A possible mitigation project could be designed around the removal of these species from areas and replacing them with native species.

There are several types of wetlands that are unique in this Region:

1) *Vernal pools.* Little is known about them. Defining them as wetlands and delineating their boundaries are problems.

It is hard to have COE take any action to protect them. Suspect they may be important to waterfowl.

2) Riparian systems. Riparian systems in this Region are special because they are not widespread and they occur in an arid area. They are primarily associated with the Lower Colorado River and the Humboldt River.

3) Diked wetlands. These occur mostly in the San Francisco area. They were formerly salt marshes that since being diked have become seasonal, freshwater marshes. It has been suggested that they substitute for freshwater wetlands being eliminated in the Imperial Valley. More needs to be known about these systems. They have been suggested as mitigation for other projects, so there is the problem of deciding whether they should be returned to tidally flushing systems or remain freshwater systems.

4) Anchaline ponds in Hawaii. These are depressions in relatively new lava which receive a mix of fresh and salt water. The water level will rise and fall with the tides due to the intrusion of salt water through the lava. They have an algae-based food chain, and contain shrimp and fish. An area of the coast where they are found is threatened with development. A Sheraton complex that is being proposed will wipe out 30% of that island's pools. Very little is known about them--how broadly they are found in the island chain or what unique species might be found in them.

5) Mangroves. The primary wetland type in the territories is mangrove swamp. Little is known about them. They have not been inventoried.

Region 10

Forested wetlands and riparian zones in the Region are the wetland types most threatened and least understood.

In Alaska there tends to be a net loss of wetlands because there is little resoration or creation. Since so much of the state is pristine it is difficult to find areas to mitigate for a project. One approach being considered is the use of mitigation banking. However, there is still the fundamental problem of how one creates or reclaims tundra or bog.

D. RESEARCH IN THE REGIONS

Region 1

A project is being conducted at Narragansett in conjunction with COE. They are testing dredge material for pollutant uptake and are developing short term bioassays.

Have recently contracted with Metcalf and Eddy to survey past mitigation projects, evaluate the success rate and make recommendations on ways to improve mitigation.

Region 2

No specific research at this time.

Region 3

The Region has funded Dr. Bill Odum to do a functional assessment of eight areas on Chincoteague Island, Virginia. He will use the FHWA Technique in the evaluation process.

The State of Delaware is sponsoring a study to evaluate the relative effectiveness of wetlands vs bulkheads in shoreline stabilization.

Region 4

The Region is supporting a study of bottomland hardwoods. Initially, the program was aimed at determining what practices EPA could ask COE to implement on Federal projects that would minimize sediment release to streams and protect forested wetlands. Research was funded to investigate how sediment inputs were related to the type of vegetation covering an area. The work was being done at COE's Waterway Experiment Station and included modelling. The next step will be to examine the process of sediment transport during overbank flooding.

Although the project began with a limited study, the work is viewed in the context of broader goals. The first objective is to determine how best to protect the remaining fragments of bottomland hardwoods that exist in the Mississippi Delta. The second is to determine what remedial measures can be applied to solve the sediment loading problems in the area. And the third is to explore the possibility of making land that is no longer used for farming available for restoration. EPA believes that the protection of the forested areas will be enhanced if they can show with good data that these systems function in sediment control.

Region 4 is also investigating the use of freshwater wetlands in wastewater management. They have recently published the first phase of an Environmental Impact Statement. This report is a comprehensive synopsis of institutional, scientific and engineering considerations associated with wetlands wastewater management systems in the Southeast. There are approximately 400 systems in existence where wastewater is diverted into a freshwater wetland.

Region 5

For a forthcoming generic environmental impact statement, Region 5 is currently studying the use of wetlands in water treatment. This will be a needed tool for decision makers. A literature review of wetland evaluation methodologies has already been compiled.

Field studies have been initiated to examine the impacts and long-term changes associated with the diversion of wastewater through wetlands. The work has been committed for two seasons. USGS is doing the hydrological work for EPA. The biological study will soon begin.

An aerial photo analysis of wastewater impacts on wetlands has been completed. Wisconsin, Minnesota, Michigan and Illinois were included in the study. Archive, as well as new photos were used to document a history. Preliminary analysis shows that over the long-term these wetlands tend to go to cattails (*Typha* spp.). There is some indication that what was there originally and how it was distributed will also influence the changes that occur with the introduction of wastewater.

Region 6

There is no research by EPA ongoing in the Region. However, a research plan for investigating the losses of Louisiana coastline is being developed, as described above.

Region 7

Have implemented a project to target areas in the Rainwater Basin which are important to the bird migrations. Would like to study the economics of filling vs not filling a wetland. Feel that with the current low price of corn that filling wetlands is probably no longer profitable.

Region 8

The Region has requested money to support a study of the seasonal water quality functions of prairie potholes and their relationship with the surrounding watershed.

Would like to develop an initiative on riparian systems with the Bureau of Land Management and FWS.

Funded the development of a community profile of the montane wetlands in the Region.

Region 9

A current research project will map the wetlands of San Francisco Bay. This process is especially important in the South Bay where development pressure is greatest.

Aerial photographs and ground-truthing will be used. Maps will be generated using the FWS computer system in Slidell, Louisiana. The maps will be produced with overlays to indicate various features of the area, e.g., vegetation type, zoning.

Region 10

The Region is involved in the advanced identification of areas in anticipation of oil and gas development in Alaska. The Alaska National Interest Lands Conservation Act of 1980, Section 1002, provides for comprehensive and continuing inventory and assessment of the fish and wildlife resources on the coastal plain of the Arctic National Wildlife Refuge, and the analysis of impacts of gas and oil exploration, development and production in these areas. In response, the Comprehensive Planning Initiative for the North Slope of Alaska was initiated by COE.

A recently published document reviews ongoing studies on the North Slope to ascertain if the scope of the existing work could serve to accomplish COE's goal to initiate a comprehensive plan. These studies are being done by a number of federal, state and local agencies. As part of the program, EPA's Alaska mapping project will develop a method for the production of aerial photographic interpretation keys for the identification of Arctic wetland habitats from color infrared photographs. This project was designed to provide support for site specific assessments of the Arctic Coastal Plain necessary for meeting Section 404 review capabilities.

APPENDIX II. SUMMARIES OF THE RESEARCH PLANS FROM THE FISH AND WILDLIFE SERVICE, AND THE ARMY CORPS OF ENGINEERS

Summary of: Division of Biological Services Research and Development, U.S. Fish and Wildlife Service. 1984. WETLAND RESEARCH AND DEVELOPMENT 5-YEAR PLAN.

Obtained From: Lee Ischinger, Leader, Wetland Ecology Group, Western Energy and Land Use Team, USFWS, Fort Collins, CO 80526.

Summarized By: J. Zedler.

Timespan of Plan: 1986-90.

Purpose of Plan: To provide information and capabilities in support of the National Wetland Inventory [this involves wetland delineation and wetland value assessment] and Habitat Resources [this involves information and technologies needed for conservation, protection and enhancement of fish, wildlife and their habitats].

Special Provisions:

Division of Biological Services will "continue to work in close cooperation with other governmental and private agencies...in the management of wetland ecosystems."

Refers to the Interagency Agreement between EPA and FWS regarding NEPA compliance, environmental review and 404 permit reviews.

MAJOR COMPONENTS OF PLAN:

A. Wetland delineation

1. Complete and maintain data bases (e.g., Wetland Plant Species List)

2. Develop, refine and test methods for wetland delineation

3. Train Service personnel in wetland classification and delineation

B. Assessing wetland functions and values

1. Maintain Wetland Values Bibliographic Database

2. Fill data gaps that were identified in the 1983 workshop on the National Wetland Values Assessment Procedure (Adamus method or WET)
    a. Quantify relationships between hydrological regimes and biotic communities (includes water quality)
    b. Determine food chain support functions of inland wetlands
    c. Determine critical habitat attributes for fish & wildlife
    d. Assess socio-economic values of wetland biotic components
3. Train staff in use of Wetland Values Database

C. Evaluate wetland impacts associated with wetland uses (permits, licenses, etc.)...i.e., assessing or predicting changes

1. Develop supplemental bibliographic data base on wetland impacts
2. Generate techniques to assess impacts (e.g., Community Modeling of impacts of Santee-Cooper project on bottomland hardwoods--this project predicts effects resulting from spoil deposition, fire, clearing, and hydrological modification); simulation models are emphasized to complement hydrologic and water quality work of COE and EPA
3. Train staff in use of data base and impact assessment

D. Improve wetland habitat management

1. Develop bibliographic data base on creation, restoration and mitigation and management of wetlands
2. Assess and evaluate existing methods; design and test new methods
3. Train staff in use of mitigation/restoration data base

Summary of: Clairain, E.J., Jr., D.R. Sanders, Sr., H.K. Smith and C.V. Klimas. 1985. Wetlands Functions and Values Study Plan, Technical Report Y-83-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Obtained From: Ellis J. Clairain, Jr., U.S. Army Engineer Experiment Station, Vicksburg, MS 39180

Summarized By: M. Kentula

Timespan of Plan: 1985-89

Purpose of Plan: To guide a multiyear research effort that will develop methods for quantifying wetlands values.

National Wetlands Functions and Values Research Priorities: The priorities listed were reproduced from Table 21 of the research plan.

PRIORITY	WETLAND TYPE AND FUNCTION
1	Bottomland hardwoods (Gulf and South Atlantic Coasts and Interior: Midcentral) o Synthesis study of hydrologic functions
2	Bottomland hardwoods, including swamps (Gulf and South Atlantic Coasts and Interior: Midcentral) o Ground-water recharge/discharge o Flood storage and desynchronization o Sediment retention o Shoreline anchoring and erosion abatement o Nutrient uptake o Denitrification o Heavy metal immobilization o Food chain production o Detrital export o Spawning and nursery habitat for aquatic biota o Waterfowl habitat
3	Freshwater marshes (Interior: North Central-Great Lakes) o Ground-water recharge/discharge o Flood storage and desynchronization o Sediment retention o Shoreline anchoring and erosion abatement o Nurtient uptake o Denitrification o Heavy metal immobilization o Food chain production o Detrital export o Spawning and nursery habitat for aquatic biota

4 Estuarine marshes (North Atlantic)
  - Synthesis study of water quality functions

5 Swamps (North Atlantic)
  - Synthesis study of ground-water recharge/discharge

6 Estuarine marshes (Pacific Coast)
  - Ground-water recharge/discharge
  - Sediment retention
  - Shoreline anchoring and erosion abatement
  - Nutrient uptake
  - Denitirfication
  - Heavy metal immobilization
  - Food chain production
  - Detrital export
  - Spawning and nursery habitat for aquatic biota

7 Swamps (North Atlantic)
  - Ground-water recharge/discharge
  - Flood storage and desynchronization
  - Sediment retention
  - Nutrient uptake
  - Denitrification
  - Heavy metal immobilization
  - Food chain production
  - Detrital export
  - Spawning and nursery habitat for aquatic biota

8 Riparian forests (Interior: Desert Steppe)
  - Winter habitat for big game species

9 Tundra (Alaska)
  - Ground-water recharge discharge
  - Flood storage and desynchronization
  - Sediment retention
  - Shoreline anchoring and erosion abatement
  - Nutrient uptake
  - Denitrification
  - Heavy metal immobilization
  - Food chain production
  - Detrital export
  - Spawning and nursery habitat for aquatic biota
  - Migratory waterfowl habitat

10 Pocosins (Gulf and South Atlantic Coasts)
  - Hydrology
  - Water Quality

11 Freshwater tidal marshes and swamps (Gulf and South Atlantic Coasts and North Atlantic)
  - Spawning and nursery habitat for aquatic biota

12 Prairie potholes (Interior: North Central-Great Lakes)
   - o Hydrology
   - o Water Quality

13 Altered wetlands (Pacific Coast)
   - o Hydrology
   - o Water quality
   - o Fish and wildlife

SOCIOECONOMIC STUDIES

These studies will be conducted for all implemented research priorities. The studies will be implemented when investigated functions are better understood. Both monetary and nonmonetary values assessments will be investigated.

OTHER IDENTIFIED RESEARCH NEEDS

Other indentified research needs are presented below by region, wetland type, and function. No attempt was made to assign priorities to these needs.

Region 1 - Alaska

Bogs
- o Habitat for migratory waterfowl

Estuarine marshes
- o Food chain production
- o Spawning and nursery habitat for aquatic biota

Region2 - Pacific Coast

Freshwater marshes
- o Ground-water recharge/discharge
- o Flood storage and desynchronization
- o Sediment retention
- o Nutrient uptake
- o Heavy metal immobilization
- o Food chain production
- o Wildlife habitat
- o Aquatic habitat

Riparian Forests
- o Flood storage and desynchronization
- o Sediment retention

Region 3 - Gulf and South Atlantic Coasts

Freshwater marshes
- Ground-water recharge/discharge
- Flood storage and desynchronization
- Nutrient uptake
- Heavy metal immobilization
- Food chain production
- Aquatic habitat

Estuarine marshes
- Shoreline anchoring and erosion abatement

Region 4 - North Atlantic

Freshwater marshes
- Sediment retention
- Shoreline anchoring and erosion abatement
- Nutrient uptake
- Heavy metal immobilization
- Food chain production
- Aquatic habitat

Estuarine marshes
- Shoreline anchoring and erosion abatement
- Food chain production

Region 5 - Interior: North Central-Great Lakes

None

Region 6 - Interior: Desert Steppe

Freshwater marshes
- Ground-water recharge/discharge
- Flood storage and desynchronization
- Sediment retention
- Shoreline anchoring and erosion abatement
- Nutrient uptake
- Heavy metal immobilization
- Wintering waterfowl habitat

Region 7 - Interior: Midcentral

None

APPENDIX III. THE INTERAGENCY WETLAND COORDINATING COMMITTEE

Mr. Jack H. Berryman, International Association of Fish & Wildlife Agencies

Dr. Hugh C. Black, Wildlife Program Manager, Wildlife and Fisheries Division, U.S. Forest Service

Mr. James Chambers, National Marine Fisheries Service

Lt. Col. Ronald Kelsey, Assistant Director of Civil Works for Environmental Programs, U.S. Army Corps of Engineers

Dr. John Hall, National Marine Fisheries Service

Dr. Heyward Hamilton, Director of Ecological Research Division, Ofice of Health and Environmental Research, Department of Energy

Mr. Pat Murphy, Terrestrial Section, Federal Energy Regulatory Commission

Mr. Walter Prybyla, Deputy Director, Environmental Management Division, Office of Environment and Energy, Department of Housing and Urban Development

Dr. Jon Kusler, Association of State Wetland Managers

Dr. Hanley Smith, Waterways Experiment Station, U.S. Army Corps of Engineers

Mr. Doug Smith, Federal Highway Administration

Mr. John Meagher, Office of Federal Activities, U.S. Environmental Protection Agency

Mr. Bill Sipple, Office of Federal Activities, U.S. Environmental Protection Agency

Mr. Carl E. Thomas, Soil Conservation Service

Dr. Laurence R. Jahn, Wildlife Management Institute

Dr. Joseph Larson, National Wetlands Technical Council

Dr. William D. Barnard, Office of Technology Assessment, U.S. Congress

Dr. Paul Adamus, developed the Wetlands Evaluation Technique while a consultant to the Federal Highway Administration

Dr. Bill Wilen, National Wetlands Inventory, U.S. Fish and Wildlife Service

Dr. J. Henry Sather, National Wetlands Technical Council

Dr. Dana R. Sanders, Sr., Leader, Wetlands Research Team, U.S. Army Corps of Engineers

Mr. Ellis J. Clairain, Jr., Waterways Experiment Station, U.S. Army Corps of Engineers

Mr. Charles DesJardins, Federal Highway Administration

Mr. Herbert Quinn, Office of Research and Development, U.S. Environmental Protection Agency

Ms. Patricia Riexinger, New York State Department of Environmental Conservation

Mr. Thomas Dahl, National Wetlands Inventory, U.S. Fish and Wildlife Service

Other Department of Interior Contacts:

Dr. John D. Parsons, Office of Surface Mining

Mr. Bill Radtkey, Division of Wildlife, Bureau of Land Management

Dr. William Walker, Biological Resources Division, National Park Service

Dr. Edward Pluhowski, Water Resources Division

Mr. Larry Roberts, Deputy Director, Office of Environmental Affairs, Bureau of Reclamation

APPENDIX IV. STATUS OF WETLAND SCIENCE
SUMMARIES OF SELECTED PAPERS

Summary of: Brinson, M. M., H. D. Bradshaw, and E. S. Kane. 1984. Nutrient assimilative capacity of an alluvial floodplain swamp. J. Applied Ecology 21: 1041-1057.

Summarized by: J. Zedler.

This paper reports on field ("in situ") experiments performed in a floodplain forest in North Carolina that held standing water for most, but not all of the year. Chambers of 1.46 square meters were pushed into the soil around a small sapling to isolate a column of water within the wetland.

Weekly additions (1 g of N or P/sq. m/week) of nitrate, ammonia, phosphate, all three combined, and secondary sewage effluent were added as individual treatments to 5 chambers; one had no additions; a final area had no additions and no chamber. [Note: Future experiments of this type should replicate all treatments.]

Four hypotheses were tested:

(i) Nitrate removal occurs principally by denitrification under anaerobic conditions.

Findings: "Nitrate loss by denitrification was rapid and persistent; only slight accumulation occurred in surface water, and soil water accumulation was undetectable."

(ii) Ammonium accumulates...during low redox conditions but is transformed to nitrate under oxidizing conditions.

Findings: "Ammonium accumulated on cation exchange sites but was transformed to nitrate during drydown of sediments in summer and autumn. As nitrate did not accumulate, a tight coupling of nitrificaion and denitrification is inferred."

(iii) Phosphorus accumulates in easily extractable forms that are readily mobilized under low redox conditions in soils.

Findings: "Phosphate accumulated in sediments principally in acid-extractable form with little evidence of loss after the additions ceased."

(iv) Rooted vegetation takes up little N and P.

Findings: "At these high loading rates, uptake of nitrogen and phosphorus by vegetation and accumulation in tree stem-wood was small in comparison with disappearance by denitrification and accumulation in sediments."

In summary, the authors state:

"The capacity of the swamp for nutrient removal was highest for nitrate, intermediate for ammonium, and lowest for phosphate." Of the nitrogen added, only 15% accumulated in the sediment and water, while denitrification losses summed to 30%. Of the phosphorus added, 46% accumulated in the soil and water.

Summary of: Dickerman, J. A., A. J. Stewart, and J. C. Lance. 1985. The impact of wetlands on the movement of water and nonpoint pollutants from agricultural watersheds. A report to the Soil Conservation Service. USDA ARS Water Quality and Watershed Research Laboratory, Durant, Oklahoma.

Summarized by: J. Zedler.

As the title implies, this is a review of information to build predictive models of wetlands to serve agricultural needs (i.e., predicting runoff, phosphorus and nitrogen losses) and manage adjacent wetlands to improve downstream water quality (i.e., the necessary wetland size, vegetation, and sediments required for water quality improvement).

The report reviews literature on wetland hydrology, wetland cycling of phosphorus, wetland cycling of nitrogen, and the capacity of wetlands to store sediments and pesticides. It includes recommendations for research and computer models. The report cites 176 references. Questions asked include:

"What value can we assign to the water quality improvement of agricultural runoff by wetlands adjacent to agricultural lands?"

"How can these and other wetland attributes be enhanced?"

The authors conclude that wetlands are "generally effective at removing both N and P on an annual cycle," based on 7 studies that adequately evaluate inputs and outputs. They also agree that wetlands reduce sediment loads.

The ability of wetlands to retain or alter agricultural herbicides and insecticides is also reviewed. The persistence of pesticides in wetlands is evalated, and several conclusions are made:

Organochlorine pesticides are highly persistent due to strong sorbtion onto soil particles and the presence of organic matter in soils. Sorptive tendency is best predicted by the compound's octanol-water partition coefficient.

Arsenate pesticides bond strongly to clays; intensity varies with pH, Fe, and phosphate. Anaerobic conditions favor arsenic release.

Excepting parathion, most organophosphorus insecticides hydroloze rapidly around pH = 7. Parathion can be degraded microbially, under either oxic or anoxic conditions.

Carbamate insecticides persist longer with low, compared to high, pH.

Phenoxy herbicides are degraded microbially, with faster rates in the presence of sediments and under warmer temperatures.

Predicting breakdown rates is "chancy," because the processes and their controls are complex; e.g., rates of degradation differ in terrestrial vs. aquatic systems; compounds that are related chemically aren't always degraded similarly.

The authors conclude that four processes dominate the fate of materials in agricultural runoff:

1) physiocochemical transformations of pollutants
2) aeration
3) biochemical transformations of pollutants, and
4) sediment adsorption.

The data base is judged best for the first three processes, and poorest for sediment-related processes. A "water-budget based hydrological model" is recommended to predict the fates of materials, with sub-models for each of these four processes. More research is recommended to develop and validate the sub-model for sediment adsorption.

The basic structure of a hydrological model is outlined in Fig. 3, p. 71, to predict the ability of wetlands to remove agricultural pollutants. This "core model" is given overall highest priority for attention, because it is the major controlling force determining wetland water quality functions. The authors believe that adequate information already exists to construct such core models. "Such a model could...be interfaced with the Small Watershed Area Model (SWAM) under development by the Agricultural Research Servce; the latter model provides reasonable estimates of the types and quantities of pollutants (sediments, nutrients, and pesticides) discharged from agricultural watersheds."

The four pollutant-controlling processes listed above would each be developed as a sub-model; the essential elements of each submodel are listed on p. 72. Importance of processes, relative to degree of understanding, is summarized in table 8, p. 74, which is a matrix of 7 pollutant categories affected by 8 processes.

Fates of settleable solids are considered most well understood, followed by P, N, heavy metals, halogenated hydrocarbons, colloidal materials, and organic compounds (most poorly understood).

Highest priority for research to feed the pollutent-controlling sub-models was assigned to the role of sediment adsorption, sedimentation/flocculation, and emulsification. Next were evaporation, chelation/complexation, nitrification/denitrification. Ranked third were: biotic uptake, decomposition, and precipitation. Specific needs within those categories included: volatilization of ammonia and influence of flocculation/filtration on dissolved organic nitrogen. In addition, fates of organic pesticides in relation to the organic and inorganic components of the sediment, cation exchange capacity of the sediment, and sorption/desorption characteristics of selected organic pesticides are poorly known.

The authors identify major drawbacks in existing studies of processes related to agricultural activities: artificial systems have been too small and field studies have lacked sufficient replication. As a result, the results do not allow for spatial heterogeneity, nutrient cycling, pollutant processing, interactions between controlling factors, and identification of cause-effect relationships.

Thus, they recommend developing an experimental wetlands facility to do large-scale manipulaive experiments with adequate replication.

Summary of: Nixon, S.W. and V. Lee. In press. Wetlands and water quality: a regional review of recent research in the United States on the role of freshwater and saltwater wetlands as sources, sinks, and transformers of nitrogen, phosphorus, and various heavy metals. Prepared by University of Rhode Island for U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Obtained from: Scott Nixon, Graduate School of Oceanography, University of Rhode Island, Kingston, RI 02881

Summarized by: J. Zedler.

Objective of paper: Presents the results of a literature review on water quality functions of wetlands. The analysis was conducted, by wetland type, for each of seven geographic regions of the United States. Recommendations are also provided to address data gaps.

This paper reviews approximately 400 papers.

RESEARCH RECOMMENDATIONS

I. Field studies

   A. Focus--Development of mass balances on budgets of carbon, nutrients, heavy metals and, perhaps, other pollutants. Studies should include several annual cycles. Exchange rates should be measured across system boundaries, including atmospheric deposition, surface and ground-water flow, nitrogen fixation, denitrification, volitization, and burial.,

   B. Considerations for field site selection

      1. Freshwater wetlands should recieve most of the attention because they comprise almost 90% of the nation's wetlands.

      2. Wetland types that are being lost or altered most rapidly should have priority for study.

      3. Wetlands that are near urban centers or large agricultural areas should be emphasized.

      4. Large systems should recieve attention, because they will attract the best research

      5. Small systems should recieve attention, because they are easier to control and measure.

6. Sites that have already been studied will allow for building on existing data.

7. New sites will attract new people to do the research and new ideas will be stimulated.

8. Sites with simple hydrodynamics and ability to develop a water budget would have priority.

C. Three to six sites should be selected for intensive study.

D. Special study needs include:

1. Measurement of rates of denitrification and nitrogen fixation are needed for hardwood swamps.

2. Sediment accretion measurements are needed in Great Sippewissett Marsh.

3. Atmospheric exchange studies and budgets for heavy metals should be included in the research sponsored by the National Science Foundation at its Long-Term Ecological Research (LTER) sites, e.g., North Inlet salt marsh in Georgetown, S.C.

II. There is a need to develop facilities with replicate microcosms with controlled hydroperiod, slope, water inflow flow rate, light, soil type, temperature, wind, etc., that are suitable for using radioactive tracers for studies of "routes, rates and reservoirs".

III. Methodology

A. Studies of nitrogen fixation should be preceeded by a study that would calibrate acetylene reduction measurements with radioactive nitrogen tracers for a representative sample of wetland soils, sediments and litter.

B. Studies of denitrification should be preceeded by intercalibration of the various techniques available to measure this process.

C. Studies of accretion rates in wetland sediments should be preceeded by comparisons of results with different isotopes (C-14, Pb-210, Cs-137, etc.) and comparisons with different types of wetlands (e.g., rapidly vs slowly accreting wetlands; wetlands with mineral vs organic soils).

Summary of: Odum, William E. In press. The role of non-tidal and tidal freshwater marshes in reducing nutrient inputs to Chesapeake Bay. In: J. Kusler (ed.), The Wetlands of the Chesapeake: Protecting the Future of the Bay. Env. Law Inst., Washington, D.C.

Obtained from: William E. Odum, Department of Environmental Science, University of Virginia, Charlottesville, Virginia.

Summarized by: M. Kentula.

Objective of paper: Examine the possible role of tidal and non-tidal freshwater wetlands in diverting nutrient inputs from non-point runoff in Chesapeake Bay.

This paper reviews approximately 25 papers.

MAJOR TOPICS

A. The problem

1. Water quality in Chesapeake Bay and its tributaries has been steadily declining.
2. It appears to be related to increased inputs of nutrients (phosphorus and nitrogen compounds) and toxic materials.

B. Wetlands as nutrient filters

1. A positive relationship between wetlands and improved water quality has been recognized for at least 50 years.
2. In the past 15 years there have been attempts to use freshwater wetlands to process wastewater.
3. A wetland's ability to improve water quality varies
    a. depends on hydrology, seasonality, soil type, vegetation type, wetland type
    b. questions and disagreement on the effeciency of different wetland types, time to become saturated, degree of degradation that may occur, whether wetlands should be used in wastewater treatment
    c. Agreement that wetlands indirectly "process" and remove nutrients from adjacent eutrophic bodies of water

4. Nutrient cycling in wetlands

    a. all have the ability to intercept and retain nutrients from water

    b. there is great variation between sites and wetland types in the seasonal pattern and length of time that nutrients are retained

    c. fresh and salt water tidal marshes act primarily as transformers of nutrients (differ from non-tidal because of the large flow of water with tides and a different soil chemistry because of high sulfur)

C. Potential nutrient interception by freshwater wetlands adjacent to Chesapeake Bay

1. Non-tidal

    a. occupy 15-20X the area of the tidal marshes

    b. know almost nothing about their role in intercepting nutrients

2. Tidal--two factors may limit their ability to intercept nutrients before they enter the bay--

    a. most are broad, therefore, much of the volume of water may not have the opportunity to be directed through the marsh

    b. lack a permanent litter layer (plant material decomposes quickly), have no standing dead and little underground peat, therefore, may release nutrients in the fall, winter and early spring

D. Recommendations

1. Tidal and non-tidal freshwater marshes should be protected from destruction and alteration as much as possible.

2. Investigate the role of non-tidal freshwater marshes in nutrient removal.

3. Investigate the use of small, artificial, non-tidal wetlands at point sources of pollution.

4. Investigate the variables which control the degree and extent of nutrient retention, e.g., hydrology, peat, surface litter, organic matter in the soil.

Summary of: Richardson, C. In press. Biogeochemical cycling in freshwater wetlands: a landscape perspective. In: Scient. Comm. on Problems of the Env. (SCOPE), Ecosystem Dynamics in Freshwater Wetlands. UNESCO.

Summarized by: M. Kentula.

Objective of paper: Reviews the fluxes, transformations and storage of nitrogen, phosphorus and carbon in freshwater wetlands. Key biogeochemical cycles are analyzed in terms of the resulting nutrient outputs from wetlands and evaluated as to how these yields influence regional landscapes.

Obtained from: Curtis Richardson, School of Forestry, Duke University, Raliegh, N.C. 27706

Summarized by: M. Kentula.

This paper reviews approximately 60 papers.

I. Generalization--wetlands are transformers of elements like nitrogen, phosphorus and carbon, and outputs are regulated by hydrologic conditions, soil adsorption and storage, and biotic uptake and recycling.

II. Nutrient outflows from wetlands

   A. The variation in chemical constituents in outflow waters among wetland types is controlled to a great degree by regional geology, climatic inputs and the nutrient status of wetlands.

   B. Marsh ecosystems appear to have the highest annual concentrations and variation in outflows of total nitrogen, total phosphorus, dissolved phosphorus, sulfate and specific conductance. The large variation may be related to the dramatic seasonal changes in water levels.

III. Seasonal retention of nutrients

   A. The death of wetland vegetation is typically followed by the rapid release to the water of 35 to 75% of the plant tissue phosphorus and somewhat smaller, but substantial amounts of nitrogen.

   B. Bogs are nutrient traps.

      1. The greatest amount of nutrient retention occurs in the spring for metals, orthophosphorus, organic phosphorus and organic nitrogen.

   2. The bog and surrounding terrestrial landscape are seasonally out of synchronization in terms of nutrient uptake and retention.

C. In terms of inorganic nitrogen, wetlands apparently are transformers rather than functioning strictly as sinks.

IV. Wetlands: a sink or source for nutrients?

A. The majority of nutrients are stored in the peat and litter compartment. More than 95% of the nitrogen and phosphorus in peatlands is found in the bound organic form and is not readily available for biotic uptake and recycling.

B. Suggests that there is a higher potential nutrient output from wetlands than terrestrial ecosystems for most elements.

C. Accumulation rates suggest a limited nitrogen and phosphorus storage capacity for wetlands if peat accumulation is the main biogeochemical mechanism being suggested for processing and storage.

D. Wetlands are apparently great transformers of inorganic nitrogen.

E. Phosphorus outputs from wetlands greatly exceed terrestrial outputs.

F. The amount of carbon exported from wetlands via hydrologic outflow is extremely high when compared to terrestrial systems.

G. Wetlands are often better transformers of nutrients than annual net retainers.

V. Global implications--the amount of carbon stored in wetlands and the potential magnitude of the carbon flux from these ecosystems as a result of drainage suggests that the role of wetlands in global carbon cycling has been underestimated.

Summary of: Sather, J.H. and P.J.R. Stuber, tech. coords. 1984. Proceedings of the National Wetland Values Assessment Workshop. U.S. Fish and Wildl. Serv., Western Energy and Land Use team. FWS/OBS-84/12. 100 pp.

Objective of paper: Provides a general appraisal, recommendations and observations relative to the FHWA's wetland assessment methodology (WET, Adamus 1983).

The Water Quality Function of Wetlands--Research Priorities

A. Cumulative impacts of the addition of nutrients, sediments and anthropogenic substances

   1. effect on ecosystem stability and resilience

   2. effect on seasonal changes and other cycles in wetlands, e.g., climatological factors (frost depth, snow depth) vs ability to process substances throughout the year

B. Water-sediment processes

   1. inputs-outputs, water budget

   2. flow processes vs nutrient retention (geochemistry of surface water, the runoff process)

   3. generation of detritus and its relation to material processing and retention

C. Microbiology of the system

D. Retention and processing of anthropogenic substances, i.e., heavy metals, toxic chemicals, pathogens, pesticides and other agricultural chemicals

   1. aspects of adsorption and possible transport with the sediment particle

   2. connections with the activities of man in and around the wetland (garbage disposals, mining, agriculture)

   3. turnover time, input-output (sinks and sources), threshold loadings

   4. processes involved in transformation and modification of substances

E. Recommend long-term studies in "type" localities

Summary of: Whigham, D.F. and M.M. Brinson. In press. WETLAND VALUE IMPACTS. In: S. Jorgenson (ed.), Ecosystem dynamics in freshwater wetlands and shallow bodies of water. John Wiley.

Obtained from: Dennis Whigham, Smithsonian Environmental Research Center, Smithsonian Institute, Edgewater, MD 21037.

Date of manuscript: 1984.

Summarized by: J. Zedler.

Objective of paper: To determine whether existing procedures can assess "the values of alternative uses and impacts that result from wetland development" and if "adequate models [are] available to assist in the management process."

This paper reviews 95 references.

MAJOR TOPICS

A. Wetland values.

Ten functions used in the Adamus procedure are defined:

- Ground water recharge and discharge
- Flood storage and desynchronization
- Shoreline anchoring and dissipation of erosive forces
- Sediment trapping
- Nutrient retention and removal
- Food chain support
- Habitat for fisheries
- Habitat for wildlife
- Active recreation
- Passive recreation and heritage value

Concludes that "assigning wetland process into functional categories is a much easier task than assigning values to those processes."

B. Issues of time and space.

Points out that "societal values tend to change over much shorter time scales than some of the processes that are responsible for wetland formation and the persistence of vegetation."

Wetland evaluation systems must specify the "boundary conditions" within which the method is being applied--local, regional,...global." Methods should be "robust enough" for used at any level or scale.

C. Wetland evaluation systems.

There are three types of proposed systems
1) qualitative (e.g., P. Adamus' WET)
    WET considers all important wetland functions
2) economic
    None considers all wetland functions
3) energy analysis (e.g., H.T. Odum)
    These integrate almost all important wetland functions
    Advantage over economic mehtods is inclusion of "externalities"

Problems with all evaluation systems:
    ecological data are insufficient
    impacts of modification can't be predicted

D. Application of methods in resource allocation decisions.

Basic problem is that wetlands are in private ownership, while their resource values are considered public.

E. Conclusions (The Problems).

Value assessment systems are available, but they don't predict impacts of proposed modifications.

At most, we are able to predict local impacts; resolution is lost in attempts, to test large-scale effects of wetland alteration.

No models exist to assess impacts of numerous small-scale changes.

F. Recommendations were brief, and differed for developed and developing countries.

"In developed countries, red flag features should be the first consideration in evaluating any particular wetland or group of wetlands." [A list of 11 such features was indentified by Larson (1976).]

"In developing countries, models are desperately needed because development decisions are not made at the local level..."

APPENDIX V. LIST OF SCIENTISTS CONSULTED IN DEVELOPING THE RESEARCH PLAN

Hollis H. Allen, U.S. Army Engineer Waterways Experiment Station
Mark Brinson, East Carolina University
Mark Brown, University of Florida
Virginia Carter, U.S. Geological Survey
John Day, Louisiana State University
Armando de la Cruz, University of Mississippi
Ed W. Garbisch, Environmental Concern, Inc.
Ralph Good, Rutgers University
Larry Harris, University of Florida
Michael Josselyn, San Francisco State University
Wiley Kitchens, University of Florida
Jon Kusler, J. Kusler Associates
Phil Larsen, EPA, Corvallis-ERL
Lyndon Lee, Savannah River Ecology Laboratory
Chester Martin, U.S. Army Engineer Waterways Experiment Station
Eric Metz, National Audubon Society
Scott Nixon, University of Rhode Island
Richard Novitzke, U.S. Geological Survey
Bill Odum, University of Virginia
Curt Richardson, Duke University
Rebecca Sharitz, Savannah River Ecology Laboratory
Safa Shirazi, EPA, Corvallis-ERL
Will Schroeder, University of Alabama
Jerry Schubel, State University of New York
Gordon W. Thayer, National Marine Fisheries Service
R. Eugene Turner, Louisiana State University
Dennis Whigham, Smithsonian Institute
Gary Witmer, Argonne Laboratory
Dan Willard, Indiana University

APPENDIX VI. WORKSHOP PARTICIPANTS

A workshop was held on October 9, 1985 in Chapel Hill, North Carolina to review a preliminary draft of this research plan. Those participating were:

Joy Zedler
San Diego State University

Mary Kentula
EPA, Corvallis-ERL

Bill Sipple
EPA, Office of Federal
Activities

Jerry Walsh
EPA, Gulf Breeze-ERL

Mark Brown
University of Florida

Jon Kusler
Assoc. of State Wetland
Managers

Bill Odum
University of Virginia

Hal Kibby
EPA, Corvallis-ERL

Curt Richardson
Duke University

Mark Brinson
East Carolina University

Dan Willard
Indiana University

Larry Burns
EPA, Athens-ERL

Carl Brunner
EPA, Cincinnati
Laboratory

Ed Kuenzler
University of North
Carolina

APPENDIX VII. LIST OF SCIENTISTS WHO REVIEWED THE DRAFT PLAN

The response from those reviewing the plan was extremely valuable in refining the final version. It was obvious that the reviewers made a substantial committment of time. The effort to make a contribution to the overall quality of the plan was appreciated.

The reviews represent a number of perspectives and are a important source of information in addition to what could be incorporated into the plan. Since it is important that this resource be available for future reference, the reviews have been placed on file with Spencer Peterson, Chief, Hazardous Waste/Water Branch, Environmental Research Laboratory, Corvallis, Oregon.

MEMBERS OF THE INTERAGENCY WETLAND COORDINATING COMMITTEE NOT LISTED ELSEWHERE

Jack H. Berryman, International Association of Fish and Wildlife Agencies

Hugh C. Black, Wildlife and Fisheries Division, U.S. Forest Service

James Chambers, National Marine Fisheries Service

Dr. Heyward Hamilton, Office of Health & Environmental Research, Department of Energy

Walter Prybyla, Office of Environment & Energy, Department of Housing & Urban Development

Carl Thomas, Soil Conservation Service

William D. Barnard, Office of Technology Assessment, United States Congress

Paul Adamus, consultant to Federal Highway Administration on wetland assessment

Ellis J. Clairain, Jr., U.S. Army Engineer Waterways Experiment Station

Bill Wilen, National Wetlands Inventory, Fish and Wildlife Service

Thomas Dahl, National Wetlands Inventory, Fish and Wildlife Service

NATIONAL WETLANDS TECHNICAL COUNCIL

John Clark, National Park Service

R. Terry Huffman, Huffman Technologies

Joseph Larson, The Environmental Institute, University of Massachusetts

Orie Loucks, Holcomb Research Institute, Butler University

Ariel E. Lugo, Southern Forest Experimental Station, Institute of Tropical Forestry

J. Henry Sather, Interagency Wetland Coordinating Committee

Arnold van der Valk, Department of Botany, Iowa State University

Milton W. Weller, Department of Wildlife & Fisheries, Texas A & M University

Eugene P. Odum, Center for Ecology, University of Georgia

Richard Novitzki, U.S. Geological Survey

William H. Patrick, Jr., Boyd Professor of Marine Sciences, Louisiana State University

William A. Niering, Biology Department, Connecticut College

Joy Zedler, Department of Biology, San Diego State University

PARTICIPANTS IN THE EPA RESEARCH PLANNING WORKSHOP

For list of participants see Appendix VI.

EPA'S 404 COORDINATORS

Doug Thompson, Region 1

Dennis Suskoski, Region 2

Randy Pompanio, Region 3

Bill Kruczynski, Region 4

Elmer Shannon, Region 5

Norman Thomas, Region 6

Robert Koke, Region 7

Gene Reetz, Region 8

Tom Yochem, Region 9

Marsha Lagerloef, Region 10

OTHER EPA PERSONNEL

Herb Quinn
Water and Land Division

Charles Jeter
Planning, Policy and Evaluation

Dave Davis
Office of Federal Activities

Bob Bastain
Office of Water Programs

Vic Biermann
Narragansett-ERL

Norbert Jaworski
Duluth-ERL

David Flemer
Water and Land Division

John Wilson
Policy, Planning & Eval.

John Meagher
Aquatic Resource Division

Allan Hirsch
Office of Fed. Activities

Victor Lambou
Las Vegas Laboratory

Glen Yager
Region 7

OTHERS

Rebecca Sharitz
Savannah River Ecology Lab

Dennis Whigham
Smithsonian Environmental
Research Center

Gary Mayer
NOAA Sea Grant College
Program

Scott Nixon
University of Rhode
Island

Lee Ischinger
Western Energy and Land
Use Team, FWS

Alan Wentz
National Wildlife
Federation

N. Jay Bassin
Environmental Management
Support

Barbara Bedford
Cornell University

John Day
Louisiana State University

Ed Pendleton
NCET/U.S. FWS

Sharon Lockhart
U.S., FWS

Millicent Quammen
NCET/U.S. FWS

APPENDIX VIII. OPPORTUNITIES FOR RESEARCH ON CUMULATIVE IMPACT ASSESSMENT AND MITIGATION TECHNIQUES

PRAIRIE POTHOLE WETLANDS MITIGATION FOR THE GARRISON DIVERSION UNIT IRRIGATION PROJECT

The prairie pothole region of North Dakota, South Dakota and Minnesota contains some of the most valuable waterfowl habitat in North America. Although comprising only some 10% of the continent's waterfowl breeding area, the pothole area produces some 50% of the nation's duck crop, as well as providing habitat for a large variety of other birds and mammals. While accurate estimates of pothole wetland losses are not available, it is estimated that less than 40% of the original habitat remains today. Destruction has been primarily due to drainage to increase agricultural acreage and sedimentation from agricultural tillage.

Although the wildlife and associated social values of prairie pothole wetlands have been well documented, little information is available which quantifies their possible water quality improvement functions such as nutrient, chemical, and organic waste removal.

In 1965 The Bureau of Reclamation was authorized to construct a large irrigation project in North Dakota known as the Garrison Diversion Unit. This plan would have resulted in the destruction of some 85,000 acres of prairie potholes and subsequently became the subject of intense controversy. Since it was authorized a number of modifications have been made to the project to reduce environmental impacts and still provide the desired agricultural benefits.

The most recent effort to reach an acceptable comprise is described in a report by the congressionally authorized Garrison Diversion Unit Commission (December 20, 1984). Among the recommendations is an acre-for-acre replacement policy to offset the loss of an estimated 14,212 acres of wetlands (mainly prairie potholes). Replacement is to be accomplished through use of wildlife lands already acquired, purchasing other land tracts and then reestablishing previously drained wetlands, and enhancing existing wetlands through improved wildlife management. The primary objective is to replace the lost lands with lands that are ecologically equivalent.

In developing the wetlands replacement plan, EPA, FWS and the Bureau of Reclamation need to address a number of concerns. Those that are relevant to the EPA research plan are:

1) How to establish the relative non-habitat value of enhancing existing wetlands to be credited toward acre-for-acre replacement,

2) How to evaluate the "ecological equivalency" of the proposed replacements, and

3) How to enhance existing wetlands and create others in a manner which optimizes all wetland values.

The mitigation efforts associated with construction of the Garrison Diversion Unit present some unique research opportunities. For example, existing and previously drained wetlands will be purchased, and restored or enchanced on a large scale. Since the mitigation effort will be carried out over a long time period (at least 12 years) an opportunity exists to try various mitigation techniques and adjust future actions based upon the measured results. Finally, the national importance of the prairie pothole area, as well as the need for research on the non-habitat values of these wetlands, has been clearly established.

[Information supplied by: Dale Vodehnal, Chief, Environmental Assessment Branch, EPA, Region 8.]

THE RAINWATER BASIN WETLANDS IN SOUTH CENTRAL NEBRASKA

The Rainwater Basin area covers parts of seventeen south-central Nebraska counties--some 4200 square miles. Nearly 260 different species of birds use the habitat provided by Rainwater Basin wetlands. Of these, 92 species nest and rear their broods in the basins. As many as 300,000 white-fronted geese, 90% of the midcontinent population, stop during their annual migration. The endangered whooping crane also stops in the area during its biannual migration. In addition, many species of furbearers and birds are permanent residents in the area. Furbearing animals such as muskrat, fox and striped skunk are abundant, as are game species, such as mourning dove, ringneck pheasant, bobwhite quail, white-tailed deer and a wide variety of waterfowl.

Soil survey maps from early in this century indicated the Rainwater Basin contained nearly 4000 marshes totalling about

94,000 acres, typically ranging in size from one to 40 acres, but with some as large as 1000 acres. By 1981, these wetlands had dwindled to 400 basins and 21,000 acres.

With the decrease in wetland acreage the waterfowl have been concentrated in the remaining areas. Fowl cholera epidemics, caused primarily by overcrowding, have been a problem in the Rainwater Basin since 1975. Nearly 200,000 ducks and geese have been killed by this disease in the past ten years. In 1980, 5% of the continental population of white-fronted geese were killed. The Rainwater Basin may be thought of a a "bottleneck" in the migratory flyway, through which increasingly fewer migrating waterfowl are able to pass.

On March 1, 1984, EPA sent a letter to the Nebraska Department of Environment Control (NDEC), FWS, and Nebraska Department of Game and Parks (NGP) expressing a concern about unregulated filling activity in the Rainwater Basin, and soliciting their views. Responses back from FWS, NDEC, and NGP confirmed that some type of action is needed to protect these wetland resources, and offered assistance and support.

Various actions are being considered which would promote the protection of the existing wetland resources. A community involvement and education program has been planned. There are aspects to the program that are relevant to the EPA research plan.

In this part of the United States fields are typically irrigated using a central-pivot system. This creates the landscape of green "dots" seen from the air. The corners and sometimes wedges of the "dots" will be left uncultivated. This unused land could be converted back to wetlands, if the public could be convinced of the worth of the project and if the techniques to create such wetlands were available.

[Information supplied by Glen Yager, Region 7.]

THE DES PLAINES RIVER DEMONSTRATION PROJECT

Wetlands Research, Inc., a not-for-profit corporation affiliated with the Open Lands Project (a local organization), is undertaking an ambitious wetlands restoration project along the Des Plaines River in Illinois.

The Des Plaines River flows directly through the project site, draining a 210-square-mile watershed, 80 percent of which is agricultural. The river is channelized, the wildlife habitat highly disturbed, water quality degraded, and flood damages occur downstream.

The project involves reconstructing a wetland where one once stood. Masses of earth will be moved to reconfigure 2.8 miles of stream bed and 450 acres of adjacent land, including three abandoned gravel pits. The polluted streamfow will be pumped to the perimeter of the site and returned to the river, regulated by water level controls. Spawning areas will be created, plant communities introduced, and a regime employed to minimize water level fluctuation and eliminate unwanted weedy growth.

The project's immediate objective is to rehabilitate the river environment. The long-term objectives are research and demonstration, and the ulimate goals are to:

1) Demonstrate the benefit of non-structured management strategies for wildlife, water quality and weed control,

2) Formulate and test rehabilitation procedures for wetlands and rivers,

3) Redirect existing environmental investment strategies and management programs, and

4) Foster the creation of better urban and rural environments.

During the course of the project, many questions will be addressed. Can water quality be restored by filtering water through a single small wetland? What is the appropriate scale? To what extent can flood stages be reduced to prevent downstream damages? What is the most efficient location for storage? How rich and stable will the created wildlife habitats be? Will the sites attract migrating water foul?

The Des Plaines River Wetlands Demonstration Project is being partially funded through the U.S. Fish and Wildlife Service. The Atlantic Richfield Foundation, as well as other corporations, and the State of Illinois are also contributing funds. The Lake County (Illinois) Forest Preserve District has contributed the land. Approximately 1.3 million dollars has been raised to fund the creation of the wetland in the spring of 1986. There may be opportunities for EPA to sponsor associated research projects.

[Information on the details of the project was exerpted from an article printed in the National Wetlands Newsletter with the permission of the publisher, the Environmental Law Institute. The complete citation is: Hey, D.L. 1985. Wetlands: a strategic national resource. National Wetlands Newsletter 7(1):8-10.]

THE WHITE TAIL FARMS PEAT MINING PROJECT

In North Carolina, White Tail Farms, an existing peat mining project, could be selected as a prototype to determine the cumulative impacts associated with wetland losses due to the activities of the industry. The owners of this private business will be developing 200 to 500 acres per year for peat mining. They have already agreed to allow research on their farm. EPA research costs would be greatly reduced, since funds would only be needed for monitoring and analysis. Mitigation research could also be conducted and the data utilized to set guidelines for the entire southeastern peatland ecosystem.

[Information supplied by Curt Richardson, Duke University.]

RESTORATION OF THE KISSIMMEE RIVER IN FLORIDA

The Kissimmee River Restoration Phase 1 Demonstration Project is one component of an overall State of Florida strategy to restore the natural values of the Kissimmee River. With channelization of the river in 1971, a 98-mile serpentine channel with an average depth of four feet was turned into a 48-mile canal, which is 30 feet deep and averages 200 feet in width. Seventy to eighty percent of the basin's original 40,600 acres of woody shrub, broadleaf marsh, and wet prairie wetlands were destroyed, resulting in the loss of highly valuable fish and wildlife habitat.

In 1984, the South Florida Water Management District began a demonstration project to field test methods for reestablishing a more natural water regime in the Kissimmee River Valley. The project, being conducted on a 12-mile stretch of the Kissimmee, is designed to divert water back into historic oxbows and former marshlands, and fluctuate water levels to correspond more closely to the natural wet and dry cycles typical of an Everglades hydroperiod. It should recreate approximately 1,300 acres of floodplain aquatic grasses and broadleaf marsh.

The $3.52 million project includes construction of weirs, culverts, and berms in the canal to divert the water back into the original river bed; construction of baffle blocks to improve the structural integrity of the existing structures; and acquisition of the floodplain which will be flooded by the project. Most of the project construction has been completed, and water has begun to flow into the old river oxbows; the remaining work should be finished by March 1986. For at least three years, state agencies will continue to monitor water quality; hydrology and hydraulics; and fish, wildlife and vegetation.

Other components of the State's Kissimmee River Restoration Strategy include:

- Monitoring the Phase 1 Demonstration Project (1985-1988),
- Completing the Water Management District's acquisition of 50,000 acres of the Kissimmee River floodplain (1985-1987),
- Creating additional wetlands habitat by restoring Paradise Run (1985-1986) and by fluctuating water levels (1987-1988),
- Expanding the existing best management practices program for the Taylor Creek-Nubbin Slough basin to include the lower Kissimmee River and thus further prevent and reduce nonpoint source pollution (1986-1988),
- Investigating the feasibility of having COE's Waterways Experiment Station develop a physical model to determine the effects of dechannelizing the canal by placing fill in it (1985-1986),

and, upon completion of the Phase 1 Demonstration Project and modeling,

- Implementing the final restoration phase, with development of a specific restoration design based upon the monitoring and modeling information from the demonstration project.

Although not yet designed, the final restoration phase could include an attempt to restore much of the meandering river and floodplain to its original hydrology, while still maintaining acceptable flood control levels for the upper Kissimmee basin and part of the lower basin. Twenty-one miles of the canal, about 43 percent of its length, would be backfilled to reclaim approximately 42 miles, or two-thirds, of the original river length. It is estimated that the project would recreate 17,500 to 20,000 acres of aquatic grasses and broadleaf marsh wetlands, depending upon actual rainfall and development of an appropriate water management schedule in the upper Kissimmee chain of lakes.

Cost estimates for the above strategy range from 97 to 134 million dollars. The project is expected to take a number of years to complete. EPA could possibly sponsor associated research.

[Information supplied by Mollie Palmer, Department of Environmental Regulation of the State of Florida.]